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REPORT ON HYDROGRAPHIC INVESTIGATIONS IN ALEUTIAN WATERS AND THE SOUTHERN BERING SEA IN THE EARLY SUMMERS OF 1953 AND 1954*

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I. Introduction

The training ship "*Oshoro Maru*" of the Faculty of Fisheries, Hokkaido Universty, has made cruises to the salmon fishery grounds in the northern part of the North Pacific and the southern Bering Sea near the Aleutian Islands in 1953 and again in 1954. The main purposes of these cruises were the drilling of cadets in navigational and fishery work, but use was made of the opportunity also to undertake oceanographic and biological researches. The results of the hydrographic investigations are dealt with in the present paper.

In the 1953 cruise the "*Oshoro Maru*" left her mother port, Hakodate, on 4th May, under the command of Captain Mishima (One of the authors) having aboard 34 crew members, 18 cadets, a chemist, a physicist and two students. During this voyage, on 18th July there happened an unfortunate accident that the No. 1 Oiler lost his life by the explosion of an air tank in the galley. On account of this unexpected event the ship had to hasten her homeward voyage abandoning the work of the original plan; she arrived at Hakodate on 22nd July. The approximate track of the ship and positions of the hydrographic stations in this cruise are illustrated in figure 1 whilst more exact locations of positions are given in Appendix.

In the 1954 cruise the ship left Hakodate on 25th May and returned there on 14th July, the track for this cruise having covered as far as Bristol Bay for practice in crab fishery (fig. 1). Captain Mishima and his 34 men, 15 cadets, an oceanographer and two students were on board the ship.

The locations of the hydrographic stations listed in Appendix were decided by position line sailing for the 1953 cruise, sometimes by merely dead reckoning under overcast sky, while on the 1954 cruise the Lo-Ran operation was adopted to get more exact positions regardless of weather conditions.

The occupation of the whole number of stations has taken so long a period, more than five weeks in the 1953 cruise and more than three weeks in 1954, that the data might be not satisfactorily valuable to ascertain the simultaneous features of the hydrography in the areas; limitation of studies is also due to inappropriate location and number of the hydrographic stations because of the unavoidable necessity of carrying out the

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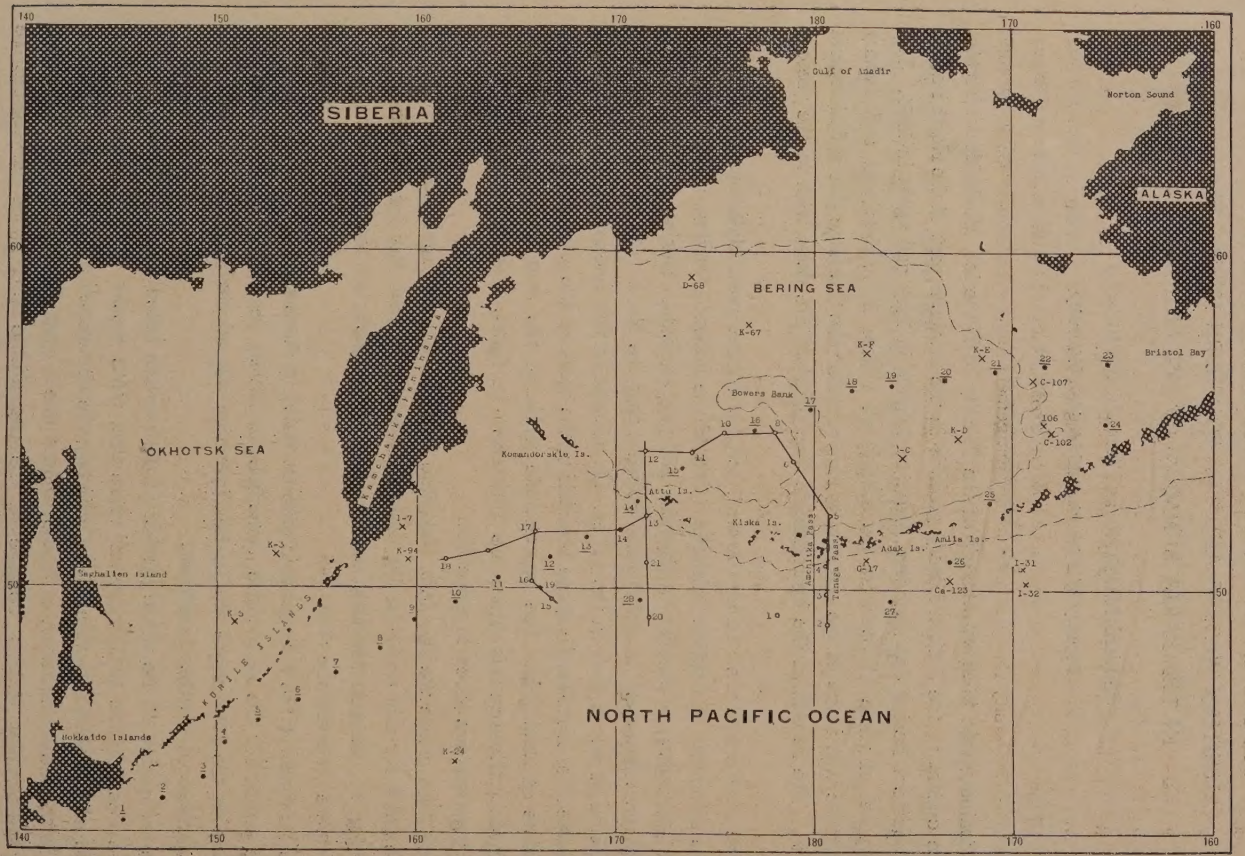

Fig. 1. Locations of the hydrographic stations occupied on the cruises of the "*Oshoro Maru*" to Aleutian waters and the southern Bering Sea in 1953 (shown with open circles) and 1954 (shown with solid circles)

Crosses show locations of some stations of previous cruises on *Komahashi* (K) in 1935 and 1936, *Itsukushima* (I) in 1935, *Gannet* (G) in 1933, *Chelan* (C) in 1934, *Carnegie* (Ca) in 1929 and *Dalinevastochinik* (D) in 1932; the materials taken at those stations on these cruises are referred to in the text.

other purposes of the cruises.

It is a pleasure to record here a debt of gratitude to Dr. Yoshitada Takenouti, the Director of the Hakodate Marine Observatory, for his kindness in criticizing the present data and in reading the original manuscript. The writers are much obliged to Assist. Prof. Hideto Koto of the University for his constructive criticism and helpful suggestions. They are also gratefully indebted to Prof. Naoichi Inoue and Prof. Sigeru Motoda of the University for their untiring encouragement and valuable suggestions throughout the course of the present investigations.

Particular thanks are due to Mr. Manichi Tochinai of the Fisheries Agency, Ministry of Agriculture, for his courtesy in providing many facilities for the present cruises. Thanks are also offered to the crew members, cadets, students and other people on board the ship, particularly to Mr. Masaomi Akagawa of the Hakodate Marine Observatory, for their hearty help during the work at sea. Their cordial thanks are also due to Miss Kyoko Shikauchi for her aid in salinity determinations.

II. General

The whole of the North Pacific above 30° north, as is well known, is dominated by the easterly flowing currents. The southern part of these currents carries warm Kuroshiwo water of high salinity while the northern part carries cold water of low salinity which is formed in successive whirls developed along the line of demarcation between the Kuroshiwo and Oyashiwo (Kurile) Currents. The latter part, comprised of so-called Subarctic Water of the North Pacific, divides into two branches when it strikes the coast of North America; the northern branch turns towards the north and flows into the Gulf of Alaska. It, then, diluted and heated in the Gulf, returns towards the west on the southern side of the Aleutian Islands (Sverdrup *et al.*, 1942; Sverdrdup, 1944). This returning flow has been ascertained by several Japanese vessels to continue as far west as to the westward of longitude 180° as has been shown in the "Current Chart of the North Pacific" compiled by the Hydrographic Office of Japan in 1936.

Along the eastern side of the Kamchatka Peninsula and northern Kurile Islands, a current of severely cold water of low salinity, probably formed in the preceding winter along some Asiatic coast, flows towards the south or southwest. One part of this current moves along the Pacific side of the Kurile Islands and there mixes with the water which has poured from the Okhotsk Sea into the Pacific through the Kurile Chain. It moves southwest along the southern side of Hokkaido Island, forming the so-called Oyashiwo Current. The intermediate layer of minimum salinity of the North Pacific, which is found down to depths below 300 m over almost the whole of the North Pacific except the region of the Subarctic Water, is formed by the subsurface mixing of the Kuroshiwo

water from the south with the submerged Oyashiwo water from the north (Uda, 1935). Another part of this cold water, on the other hand, thrusts south directly into the Subarctic Water between longitudes 150° and 160° east, and spreads towards the east (Sverdrup, 1944). This severely cold water below 3° is found on either side of the Aleutian Islands as far east as longitude 175° west.

Waters of high temperature and low salinity extend over the shallow eastern region of Bering Sea especially in Norton Sound and Bristol Bay. In the northern part of the Bering, in the vicinity of the Gulf of Anadir, there originates abnormally cold water below 0° due to the severe winter cooling and ice melting. The deep portion of the Bering, however, is occupied by a water mass which is very much similar to the Subarctic water of the North Pacific. The general circulation of water in the Bering is counter-clockwise, and the shallow water from the Pacific pours into the Bering through any of the channels between the Aleutian Islands and sets east parallel to the chain of the Islands on the north side of it. In the eastern part of the Bering, waters moves north or northwest following the bottom contours of the eastern Bering. The warm water of low salinity found along the Alaskan coast moves also towards the north. These currents pass through the Bering Strait and finally pour into the Arctic Ocean (Barnes & Thompson, 1938; LaFond & Pritchard, 1952).

III. Temperature and Salinity

Vertical Distribution

The values of temperature and salinity obtained in the present observations in 1953 and 1954 are contained in Appendix, and in several vertical sections isotherms and isohalines are drawn in order to bring out the characteristic features.

As may be easily seen from these figures, in the shallow layers above 400 m the observations yield data within wide ranges in both temperature and salinity. The salinities increase very rapidly especially below 150 m, while in deeper layers, the observations converge on the characteristic values of the Subarctic Water of the North Pacific; salinity increase and temperature decrease with increasing depth are slow and uniform, attaining 2.6—2.9° in temperature and 34.4—34.5 ‰ in salinity at a level of 1000 m.

The homogeneous convection layer at the surface is very thin or can not be found at all in these regions during the period of the present investigations. The surface temperatures lie between 2.5° and 5.5°, and surface salinities between 32.8 ‰. With increasing depth, the temperature decreases rapidly at all stations, and salinity also decreases slightly at most of the stations down to about 100 m. The most conspicuous and interesting feature of stratification in these regions is the existence of a subsurface layer*

* The writers will, for convenience, use the terms *the subsurface layer* of minimum temperature for the cold layer below 3° found at a level of about 100 m, and *the intermediate layer* of maximum temperature for the warm layer found at a level of about 300 m.

of severely cold water of low salinity at about 100 m depth. The values of the minimum temperature of this layer in the present regions lie between 0° and 3°. Beneath the subsurface layer the temperature increases with increasing depth and at about 300 m level it reaches intermediate maximum values* above 3.5° followed by slow decrease below this level. The salinity, on the other hand, increases rapidly below the subsurface layer of minimum temperature and continues to increase slowly down to 1000 m level.

In Section I (stations 2 to 8, figs. 2-a and 2-b), which runs north and south in longitude 170° west, the surface water is very high in temperature and very low in salinity especially in the Pacific south of the Aleutian Ridge. At station 4 the temperature is above 5° and the salinity is below 33 ‰. The warm surface layer above 4° covers stations 2, 3 and 4 in the Pacific and station 5 in the Bering, but this layer vanishes to the north of station 5 in the Bering.

Below the topmost layer, the temperature decreases with increasing depth and shows a minimum at a level of approximately 100 m, except at station 5. The minimum, however, is not very pronounced, the lowest values being higher than 2.5°. It is of interest to note that the subsurface cold layer in the Pacific has higher temperatures and lower salinities than that of the Bering; the axis of the minimm temperatures in the Pacific has a temperature of 2.9° and a salinity of 33.2 ‰ at station 3, while the axis in the

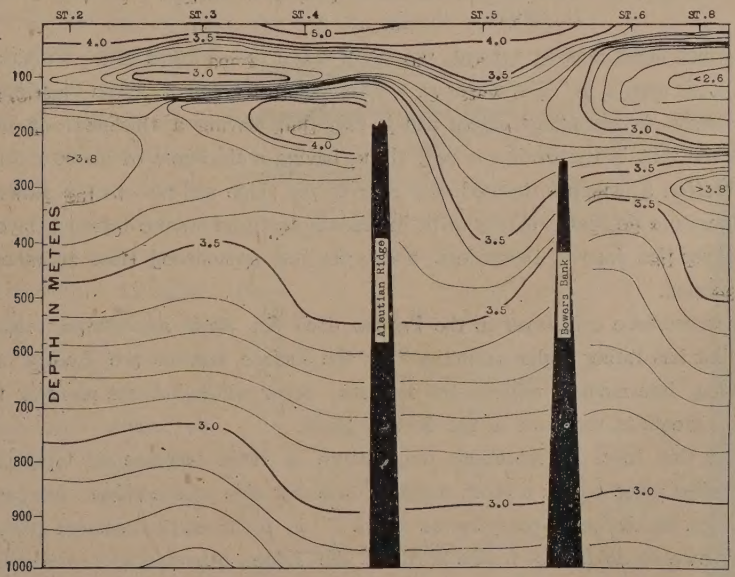

Fig. 2-a. Vertical distribution of temperature in Section I on May 15 to 18, 1953

* See the foot-note in p. 88

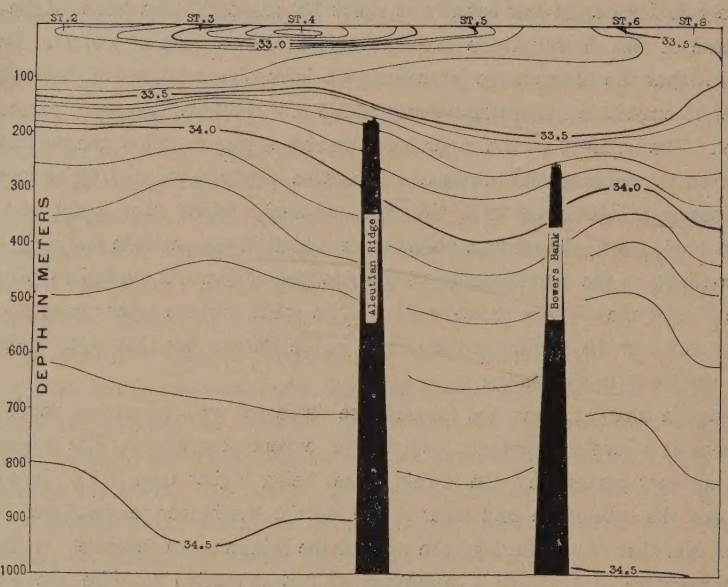

Fig. 2-b. Vertical distribution of salinity in Section I on May 15 to 18, 1953

Bering which sinks slightly towards the south has a temperature of 2.5° and a salinity of 33.4 ‰ at station 8. The water of low temperature below 3° in the Pacific, moreover, is very narrow in meridional extent and is very thin, having a thickness of only about 15 m, while that in the Bering is very thick, having a thickness of about 150 m.

At station 5, which is located very near to the ridge and also to the Bowers Bank, the temperature decreases slowly with increasing depth below the topmost layer; a minimum layer lies deep at 150 m level and is far less pronounced than at other stations in this section.

The subsurface cold layer in the Pacific does not show any distinct minimum of salinity but has rather higher salinities than the surface, but in the Bering several irregularities, intermediate minima and maxima, occur which indicate more or less complicated currents to the west of the Bowers Bank.

Below this level of minimum temperature, a rapid increase of temperature and salinity takes place within a short distance on either side of the ridge. At station 4, an intermediate maximum of temperature above 4° is found at a level of 200 m. which, however, extends no farther to the north of the ridge. At station 3, the intermediate maximum is less pronounced than at station 4 and than at station 2 also, where a thick homogeneous layer of water higher than 3.8° but lower than 4° in temperature is found to lie between 150 m and 300 m levels. The intermediate layer of maximum temperature

in the Bering lies deeper than in the Pacific and is less pronounced especially at station 5 where it lies deep at a level of 500 m, having a temperature of 2.5°.

The salinity increase below the subsurface cold layer is so much more rapid in the Pacific than in the Bering that the isohaline of 24 ‰ which lies at a level of 200 m in the Pacific suddenly sinks down to a level of 400 m to the north of the ridge approximately following the course of the isotherm of 3.5°. It is a conspicuous feature in this section that the isohalines of 34.20 ‰ and more as well as the isotherms of 3.5° and less below the layer of maximum temperature, rise towards the north between stations 2 and 3, and sink suddenly to the north of station 3, indicating that an accumulation of cold saline water takes place at station 3 and another accumulation of warm and less saline water takes place at station 4 down to a depth of about 900 m. This suggests the existence of a easterly current to the south of station 3 and a westerly current to the north of the same station.

The water below a level of 800 m decreases in temperature and increases in salinity gradually with increasing depth reaching about 2.8° of temperature and 34.5 ‰ of salinity at a level of approximately 1000 m in this section.

In Section II (stations 12, 13, 20 and 21, figs. 3-a and 3-b), which runs along the meridian in longitude 172° east, different features are found in the vertical distributions of temperature and salinity from those in the preceding section.

The surface temperature is lower than in Section I; the highest value 3.90° is found at station 21 where the surface salinity is 33.0 ‰, considerably higher than the surface value at station 4 in Section I. The surface temperature decreases to both sides of station 21, especially rapidly towards the north; to the north of the ridge, the surface temperature is below 3.2°. The surface salinity, on the contrary, increases to both sides of station 21, and at station 20 in the Pacific and at station 12 in the Bering it shows equally 33.30 ‰.

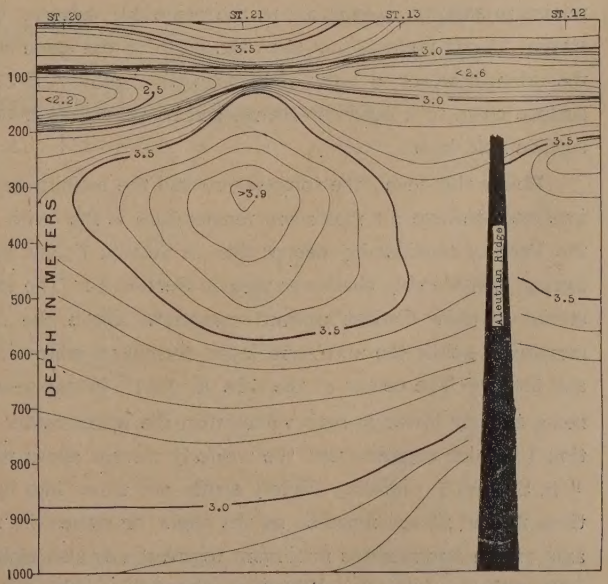

Fig. 3-a. Vertical distribution of temperature in Section II on May 20 to June 6, 1953

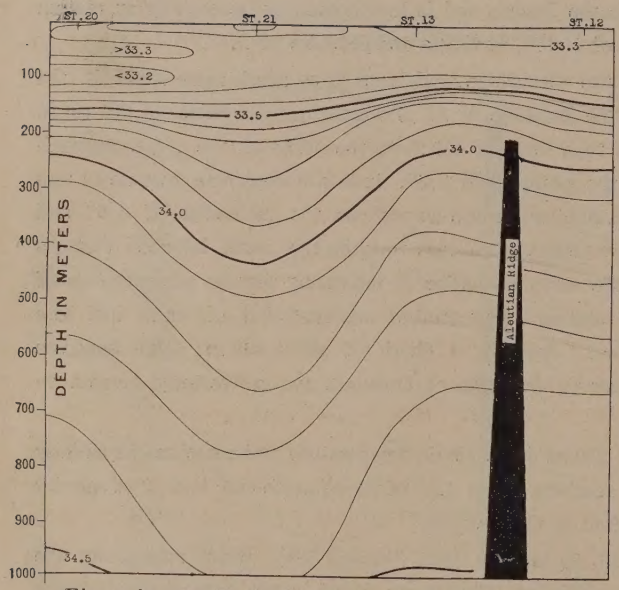

Fig. 3-b. Vertical distribution of salinity in Section II on May 20 to June 6, 1953

Remarkably developed subsurface cold layer below 3° is found through the section at a level of 100 m. At station 20 the subsurface minimum is especially well developed, having a value of 2.1°. The axis of minimum temperature rises towards the north between stations 20 and 21 increasing the minimum value itself. Towards the north from station 21, the axis runs approximately horizontally at a level of 100 m, and the minimum value again decreases slightly but remains above 2.5°. This subsurface layer of minimum temperature is also a layer of minimum salinity, in contrast to the preceding section, below 33.25 ‰ to the south of station 21 and below 33.28 ‰ to the north of the same station. On the Bering side of the ridge, however, a layer of homogeneous salinity of 33.30 ‰ is found to lie from the surface down to a depth of 100 m, and no minimum of salinity can be found in the subsurface cold layer.

Below this level, the temperature and the salinity increase with increasing depth; an intermediate layer of maximum temperature is met with at a level of about 300 m in the Pacific, considerably deeper than in Section I, and at a level of about 250 m in the Bering, considerably shallower than in Section I. The isotherms of 3.5° and more at station 21 show distinct upward curvatures above the maximum layer and downward curvatures below the maximum layer, forming a warm core at depths of between 200 m and 550 m. The center of the core is 3.94° in temperature and 33.83 ‰ in salinity, being slightly lower in both values than the warm center of the westerly current in Section I, which suggests that the westerly current above mentioned protrudes from station 4 in Section I, bending slightly south, and flows into the present section between stations 20 and 21 accompanied by the slight decreases in temperature and salinity. The axis of the intermediate maximum temperatures also sinks from east to west in accordance with the development of the subsurface cold layer. The distinct downward curvature of isotherms and isohalines below 300 m at station 21 indicates a marked

downward transport of warm water down to a level of 1000 m or more. Thus, there occurs a considerable accumulation of light water at station 21, suggesting a development of a large whirl with its center at the station which rotates clockwise in the Pacific south of the ridge.

In Section V (stations 13, 14, 17, 18′ and 18, figs. 4-a and 4-b), which runs practically east and west between latitudes 51° and 52° north, the surface water higher than 4° in temperature covers the area between stations 14 and 17, and the surface temperature decreases to both sides. The surface salinity, on the other hand, is 33.30 ‰ at station 14 and 17, and increases to both sides. The surface layer higher than 3° in temperature is thinner than in the preceding two sections, and the thickness decreases from east to west, while the subsurface cold layer, the axis of which lies at 100 m level, increases in thickness from east to west, the minimum temperature itself rapidly decreasing.

The lowest temperature of the subsurface layer obtained in the 1953 cruise, 0.01°, is found at the westernmost station 18. At station 14, where a continuation of the warm core of the westerly current, found in Sections I and II, is met with at a level of 300 m, the minimum temperature in the subsurface cold layer is 2.82°, higher than at other stations in this section. The layer of minimum temperature in this section is also the layer of minimum salinity below 33.25 ‰ just as in Section II.

Below this level, the warm core above mentioned lies at a depth greater than 200 m

Fig. 4-a. Vertical distribution of temperature in Section V on May 20 to June 1, 1953

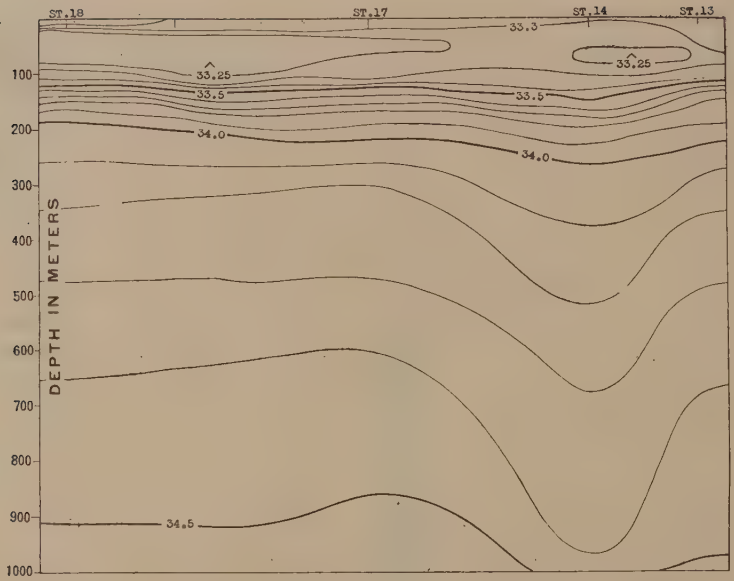

Fig. 4-b. Vertical distribution of salinity in Section V on May 20 to June 1, 1953

at station 14 and there is also found a remarkable downward transport of warm water as deep as 1000 m or more as in Section II. The large clockwise whirl, of which the vertical structure in the meridional direction has been noted in the preceding section, reveals its vertical structure in the east and west direction in this section.

It is noteworthy that in the western part of this section a distinct sinking of severely cold water below 1° takes place at station 18′ at a level of 150 m. At station 18 the intermediate maximum temperature is 3.42°, higher than the value at station 17, which suggests the existence of another current as discussed below.

In Section III (stations 15, 19, 16 and 17, fig. 5), which again runs north and south in longitude 166° east and bends at station 16 towards the southwest, the subsurface cold layer is especially developed at station 19 where the isotherms of 3° and less show a

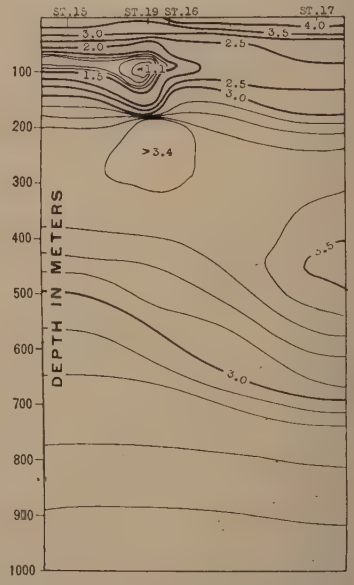

Fig. 5. Vertical distribution of temperature in Section III on May 24 to June 2, 1953

slight ascending motion of the cold water above a level of 100 m and a slight descending motion below this level. The values of minimum temperature increase to both sides, especially rapidly towards the north, from station 19.

At station 17 the western end of the warm core of the large clockwise eddy above mentioned is found at a level of about 450 m while another warm water mass above 3.4°, probably the continuation of the warm water found at an intermediate layer at station 18, lies just below the subsurfae cold layer at station 19. The isotherms of 3.3° and less rise towards the south especially rapidly between stations 17 and 16.

In Section IV (stations 12, 11, 10 and 8, figs. 6-a and 6-b), which runs practically east and west in the Bering parallel to the Aleutian Islands, no surface water is found above 4° in temperature which has always been met with in every previous section in the Pacific. At station 11, a remarkable ascending motion of cold subsurface water takes place resulting in low surface temperature below 3° and low surface salinity below 33.3‰. The surface salinity increases towards the east and at station

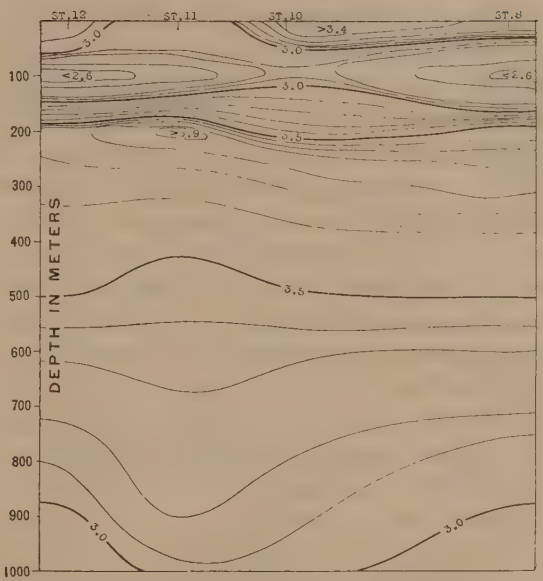

Fig. 6-a. Vertical distribution of temperature in Section IV on May 18 to 20, 1953

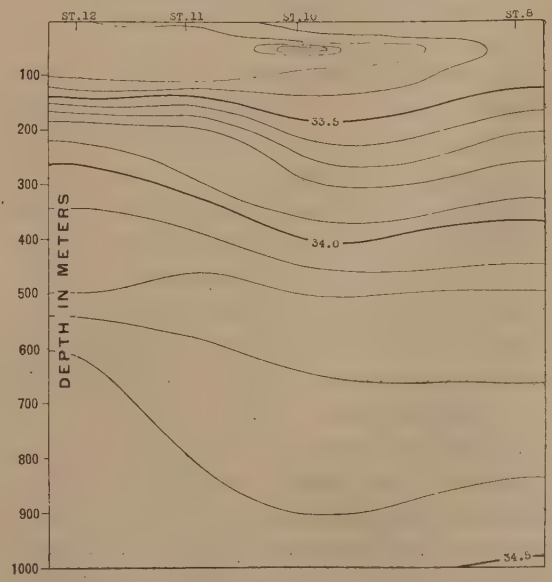

Fig. 6-b. Vertical distribution of salinity in Section IV on May 18 to 20, 1953

8, is found a high surface salinity greater than 33.5 ‰.

At a level of 100 m, there lies a subsurface cold layer, but the values of minimum temperature are above 2.5°, higher than at the Pacific stations in the previous sections. It is of interest to note that a subsurface layer of low salinity below 33.3 ‰ is found between 10 and 100 m at shallower levels than the subsurface cold layer; several irregular fluctuations in salinity are found there indicating more or less complicated currents. At station 10, the subsurface minimum of temperature is high being above 2.8° and the surface water has also a high temperature above 3.4°. Between stations 8 and 10 to the west of the Bowers Bank is found a unique spot where the water has a subaurface layer of minimum temperature below 2.6°. The salinity of this layer is above 33.4 ‰ which is considerably higher than the salinity values of the subsurface cold layer found in the Pacific sections.

The intermediate layer of maximum temperature in this section is also less pronounced than in the Pacific sections and the axis of maximum temperature sinks towards the east from 200 m depth at station 12 to 300 m depth at station 8, the maximum values themselves decreasing slightly.

Below this level, the isotherm of 3.5°, accurately following the isohaline of 34.20‰ rises towards the east between stations 12 and 11, and sinks very gradually to the eastward. But below a level of 600 m, the isotherm of 3.0° as well as the isohaline of 34.40 ‰ sinks below a level of 1000 m at stations 11 and 10, and then rises slowly as it proceeds towards the east. The isotherm of 3.0° in the Pacific sections, on the contrary, lies always above a level of 1000 m. These distributions indicate a descending movement below a level of 600 m; there is a suggestion of large clockwise rotation of the whole water body enclosed by the Aleutian Islands and the Bowers Bank.

In the cruise of the "*Oshoro Maru*" in 1954, twenty-eight stations were occupied; twenty-two of them were located along an extended section which, comprising stations 1* to 22, runs from off Hokkaido Island towards the east-northeast to Bristol Bay (fig. 1). The distributions of temperature and salinity in this whole section are shown in figures 7 a and 7-b. The section includes regions of different character. Therefore, the writers will first deal with the Central Part of the section which lies in approximately the same areas as that of the 1953 cruise, namely, stations 7 to 16.

General features of the vertical stratification in this part are almost similar to what were found in the preceding year excepting a few points. Waters in the Bering to the west of the Bowers Bank are found generally to be warmer and less saline than in 1953. The warm surface water of higher temperature than 4° was not found in the west of the Bowers Bank in the Bering in the 1953 cruise, but in this year, a thin surface layer

* The station numbers in the 1954 cruise shall be shown by underlined figures so as to be easily distinguished from the station numbers in the 1953 cruise.

Figure 7-a. Vertical distribution of temperature in the whole section covered on May 26 to June 8, 1954

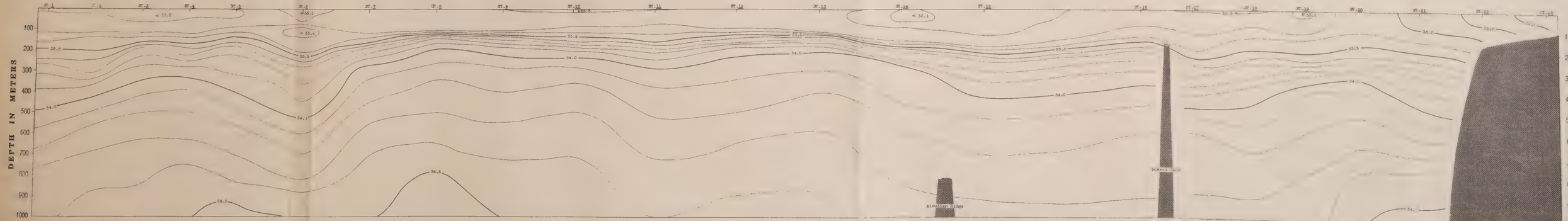

Figure 7-b. Vertical distribution of salinity in the whole section covered on May 26 to June 8, 1954

above 4° in temperature and below 33.2 ‰ in salinity is found to extend from station 14 into the Bering Sea forming a very thin skin layer. The temperature of the subsurface cold layer in the Bering is also slightly higher and the intermediate layer of maximum temperature above 3.8°, being laid across the Aleutian Ridge, is developed much thicker than in the preceding year.

In deeper layers, the isotherm of 3.0°, which as well as the isohaline of 34.40 ‰ runs undulating up and down at levels between 600 m and 800 m in the Pacific, suddenly sinks below 1000 m in the Bering, indicating the occurrence of a higher development of downward transport to the west of the Bowers Bank in this year than in 1953.

The values of minimum temperature in the subsurface layer generally decrease from east to west in the Pacific with several irregularities which have resulted from successive whirls. This is the same tendency as was found in 1953. The subsurface layer of minimum temperature does not always have minimum salinity, but it is of interest to note that the subsurface cold waters at station 7, 8, 10 and 13, where the currents have more or less remarkable components directed towards the south as computed below, are lower in temperature than at the adjacent stations and have salinities which lie in the narrow range between 33.21 and 33.26 ‰. The low salinities of the subsurface layer of minimum temperature at stations 14 and 15 is apparently a result of the dilution by the fresh surface water of high temperature. At station 16 in the Bering the cold water which has similar character to the water found at station 8 in the 1953 cruise is met with in this year also.

The intermediate warm core of the large clockwise whirl in the Pacific which is similar to that found at station 14 in the 1953 cruise, lies at station 11 in this year.

Between stations 7 and 10, is found a homogeneous water mass which has a cold shallow layer below 1° in temperature and an intermediate layer of maximum temperature of about 3.45° at a level of 300 m. This water, which is very much similar to the water found at station 18 and 19 in the 1953 cruise seems dominantly to originate in the Bering as discussed below.

In the Southwestern part of the section (stations 1 to 6), the surface water decreases in salinity below 33.2 ‰ and increases in temperature above 2.0° towards the southwest, indicating that an accumulation of light water takes place in the shallow layers. The subsurface cold layer is very cold, below 1°, and a remarkable mass of cold water is found at stations 2 and 6. At station 6 the minimum values of the subsurface cold layer is 0.64°, the lowest temperature obtained in this year in the Pacific, although it is considerably higher than the lowest one of 0.01° obtained in the subsurface layer at station 18 in the preceding cruise. The difference, however, can not be attributed to annual variation only but may also be due to the deviation of geographical positions where the observations were taken. According to Uda (1935) the temperatures of the subsurface

layer in these regions are considerably different from place to place according to the unhomogeneity of cooling effect in winter season in the area where this water has been originated.

The maximum temperature of the intermediate layer, decreasing from east to west, suddenly falls below 3° between stations 7 and 6, and at the latter is found a distinctly cold water mass lower than 2.5° down to a level of about 500 m. The isotherms as well as isohalines below a level of 100 m show remarkable downward curvatures at station 6. The same but less pronounced situation is found at station 2.

The intermediate layer of maximum temperature lies very deep between 400 m and 600 m, and the values of maximum temperature are lower than 3.0° except at station 4 where the temperature is slightly higher than 3° at a level of 400 m. The isohalines of 33.50 ‰ and above sink rapidly towards the southwest, indicating that the fresh water of the Oyashiwo Current flows south or southwest at station 1.

The remarkably cold water found in this area is considered to have come from the Okhotsk Sea through the Kurile Chain as discussed below. The conspicuous undulations of isotherms and isohalines in this area suggest a complicated development of the system of currents.

In the Eastern Part of the section, comprising stations 17 to 23, which runs practically west and east from the Bowers Bank to Bristol Bay in latitudes of 54° to 56° north, the general features are considerably different from those of the former regions.

The fresh water of Bristol Bay lower than 33 ‰ in salinity protrudes towards the west to station 21 in a shallow layer above 100 m, while the surface temperature increases westward from Bristol Bay attaining 5.3° at station 21, and then decreases towards station 18 where the value is below 4°. At station 16, it increases again above 4° but decreases again below 4° to the west of the Bowers Bank. The surface layer at station 20 has a uniform salinity of 33.4 ‰ down to a level of 100 m, which is the highest value found at the surface in the whole section. Proceeding towards the west, the surface salinity decreases below 33.2 ‰ at station 19 but increses again slightly at stations 18 and 17 to a point above 33.3 ‰.

In the subsurface depth, a distinct layer of minimum temperature is found to lie also in this region at a level of 150 m, which is deeper than in the western regions in both the 1953 and the 1954 cruises. The minimum values lie between 2.0 and 3.0° with increase towards the west from 2.0° at station 20 to 2.88° at station 17. The salinity, however, increases with greater depth below the surface; no minimum of salinity can be found in the subsurface layer of minimum temperature in which the salinity lies between 33.40 and 33.46 ‰.

In the central part of Bristol Bay, is found a severely cold bottom water below 0° with low salinity 31.20 ‰ just beneath the surface water of high temperature, but it

seems not to spread out of the Bay beyond the continental shelf.

At a level of 300 m, there lies a layer of intermediate maximum temperature above 3.5° which stretches from the continental slope of Bristol Bay towards the west but never extends to the west of the Bowers Bank. The isotherm of 3.5°, above the maximum temperature, sinks as it proceeds towards the west from the continental slope; between stations 17 and 18 it sinks down suddenly to connect there with the isotherm of the same temperature which runs below the layer of maximum temperature undulating up and down, approximately following the isohaline of 34.20 ‰.

Below this level, isotherms rise towards the east along the continental slope, and isohalines, rising towards the east following isotherms between stations 18 and 20, sink, however, towards the continental slope to the east of station 20. At stations 20 and 21, a distinct accumulation of water of salinity higher than 34.4 ‰ is recognized which can not be found at other stations in the Bering above a level of 1000 m in the 1954 cruise. This extremely saline water seems to suggest an occurrence of upwelling in this area as discussed below.

Horizontal Distribution

The main features of the horizontal distribution of temperature and salinity have already been discussed to some extent; therefore, no details will be entered into but only the most important features will be pointed out.

Surface (figs. 8-a and 8 b) ····· In the observation of 1953, the warm surface water above 5.5° and of salinity lower than 33 ‰ is found at station 4 in the Pacific.

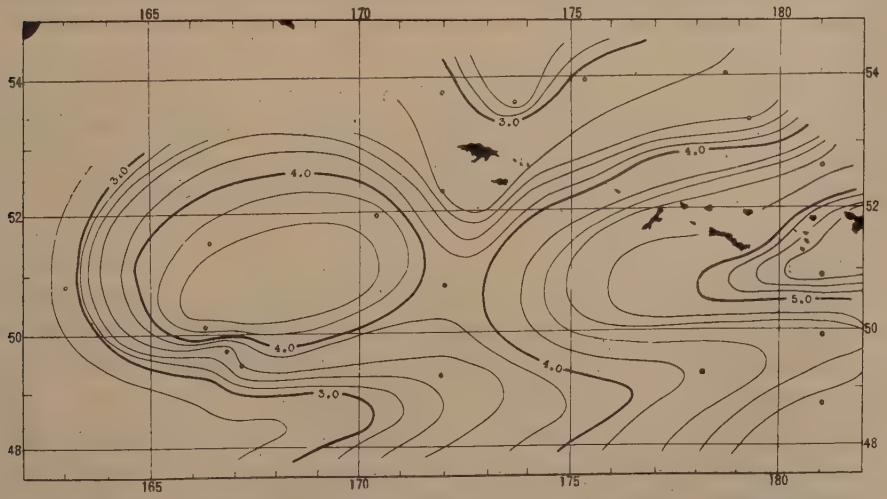

Fig. 8-a. Horizontal distribution of temperature at the surface on May 14 to June 6, 1953

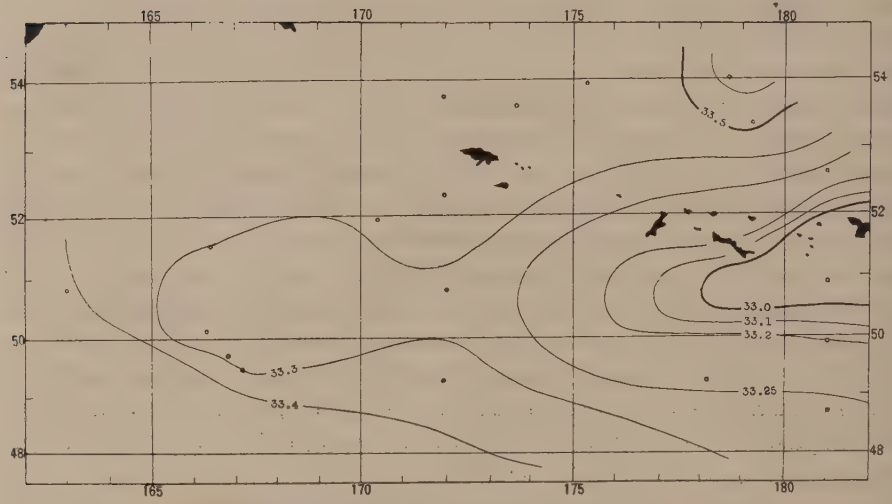

Fig. 8-b. Horizontal distribution of salinity at the surface on May 14 to June 6, 1953

This water extends towards the west along the Aleutian Islands decreasing gradually in temperature and increasing in salinity. To the west of longitude 165° east, however, no surface water is found higher in temperature than 4° and there occurs rapid decrease in temperature and rapid increase in salinty. The isotherms of 3.5° and higher as well as the isohalines of 33.30‰ and less extend farther north, passing through the Aleutian Islands into the Bering, where they run, bending towards the east, almost parallel to the islands chain.

To the south of the warm water, at a latitude of about 50° north, there is found a narrow tongue of cold surface water which protrudes east from station 18 rapidly increasing in temperature and crosses longitude 180° forming a very narrow belt. This tongue, however, has rather higher salinity than the warm water which flows to the north of it.

To the south of this cold water, a warm and saline water is found at station 2, which is undoubtedly the continuation of the northern branch of the Kuroshiwo Extension or the Aleutian Current. The demarcation line between the Aleutian Current and the cold tongue to the north of it lies between 47° and 45° north (Komahashi cruises in 1934, 1935 and 1936), but the present cruises do not cover it.

In the central part of the regions of the 1954 cruise, the general features are found to be not much differerent from those found on the 1953 cruise.

One hundred-meter level (figs. 9-a and 9-b) ····· Here the distribution of temperature is practically the same as at the surface. The cold water, protruded from the

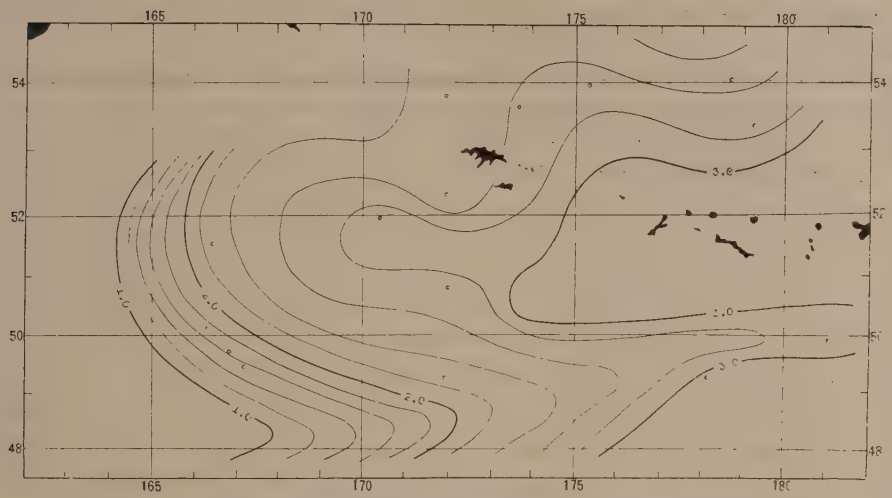

Fig. 9-a. Horizontal distribution of temperature at a depth of 100 m on May 14 to June 6, 1953

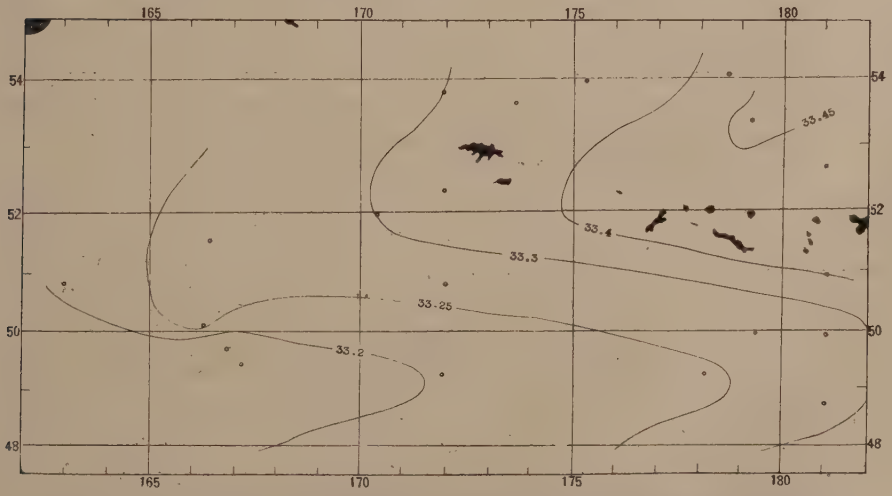

Fig. 9-b. Horizontal distribution of salinity at a depth of 100 m on May 14 to June 6, 1953

west, is found highly developed in this level and the temperature gradient is very great to the west of station 17 and to the south of station 15. As to the distribution of salinity, on the other hand, it is much different from the distribution at the surface; the warm water from the east increases but cold water from the west decreases in salinity with increasing depth, leaving the courses of the isohalines almost similar to those on

the surface. Here the tongue of cold water is found also to be a tongue of low salinity below 33.3 ‰.

In the central part of the section covered by the 1954 cruise, the surface layer of warm water of low salinity extending from the east is thicker than in 1953 and the distribution of salinity at the level of 100 m depth is practically similar to the surface.

Three hundred-meter level (figs. 10-a and 10-b) ····· Here also, the distribution

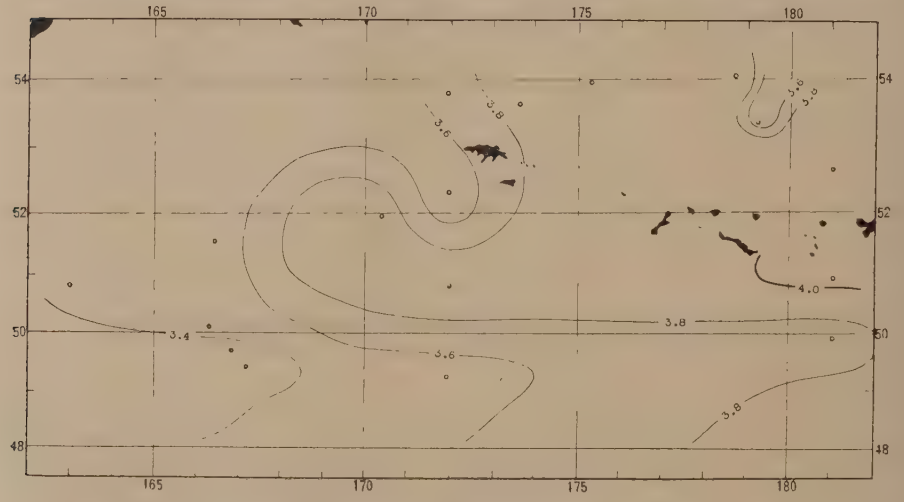

Fig. 10-a. Horizontal distribution of temperature at a depth of 300 m on May 14 to June 6, 1953

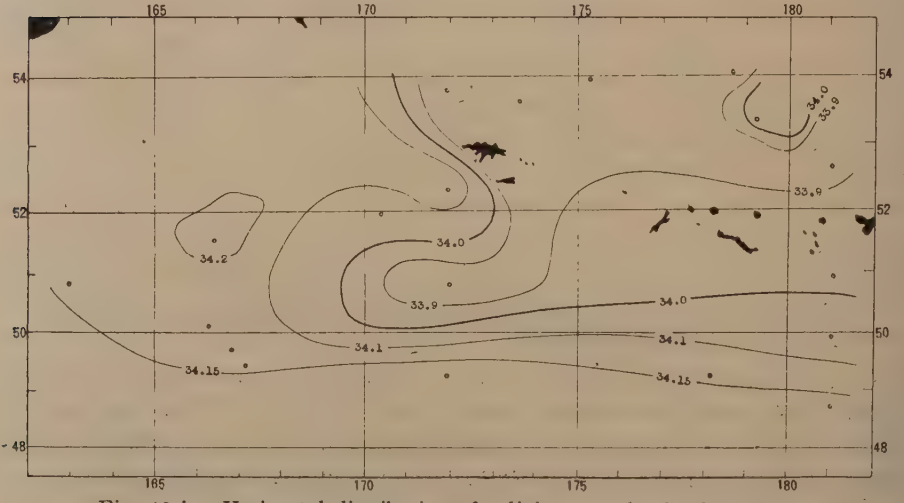

Fig. 10-b. Horizontal distribution of salinity at a depth of 300 m on May 14 to June 6, 1953

of temperature is almost the same as before, but, the temperature contrasts are smaller. The horizontal gradient in temperature to the west of station 18 is very small.

The distribution of salinity, however, is very different from that at 100 m level. The tongue of low salinity disappears and general increase in salinity towards the south takes place, resulting in approximately the same character of distribution as that of the surface.

The same character of temperature and salinity distribution as that for 300 m level can be found at the deeper levels though with still smaller contrast of values. The section covered by the 1954 cruise shows especially that the Bering water from off Attu Island to the Bowers Bank is distinctly less saline and higher in temperature at deep levels than the Pacific water to the west of the Aleutian Ridge. Towards the western part of long section, temperature and salinity decrease with several irregularities and continue to the fresh and cold Oyashiwo water, while towards the eastern part of the section temperature decreases and salinity increases.

IV. Water Mass Analysis

As stated before, a distinct water mass of high temperature and low salinity is met with along the southern side of the Aleutian Islands. The temperature salinity diagrams for station 4 and 21 (fig. 11) shows the characteristic properties of this water at differnt levels and in different regions. Extremely low surface salinity suggests some coastal origin of this water. Barnes & Thompson (1938) found similar water at *Gannet*-stations

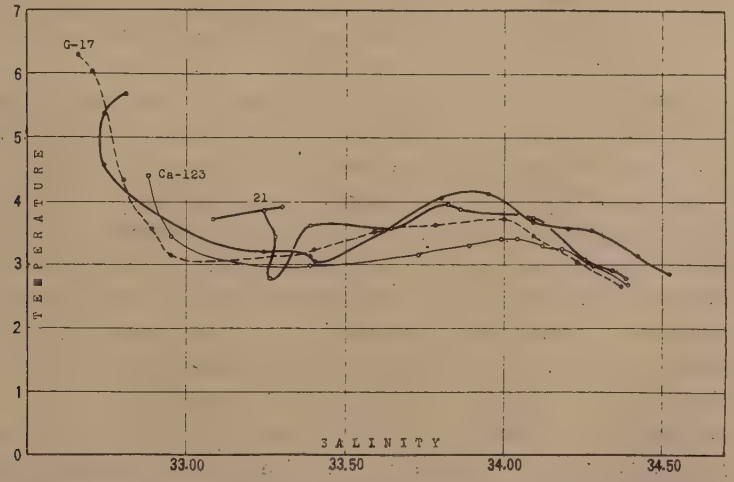

Fig. 11. T-S curves of the westerly current on the southern side of the Aleutian Islands in 1953. The T-S relations at *Gannet*-station 17 and at *Carnegie*-station 123 are also included. Locations of stations are shown in figure 1.

16 (51-12 N, 177-14 W) and 17 (50-55 N, 177-10 W) to the south of Adak Island in June 1933 (fig. 11), and ascertained the northward movement of this water by the computation of dynamic meters above 1000 m level. This water, however, differs apparently from the water of the Aleutian Current which is considerably lower in temperature and higher in salinity as characteristically represented by T-S curve for *Carnegie*-station 123 (50-27 N, 172-51 W) as included in the same figure. In the 1954 cruise, similar water is found at station 26 to the south of Amlia Island (fig. 12). In both 1953 and 1954,

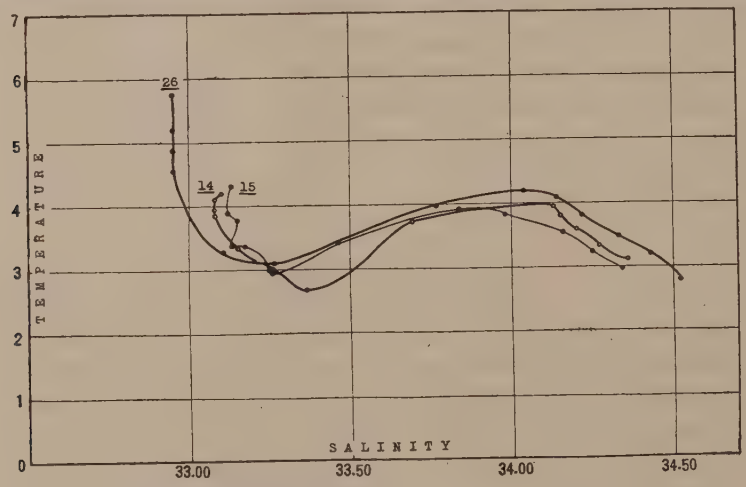

Fig. 12. T-S curves of the westerly current on the southern side of the Aleutian Islands in 1954

the fresh surface layer of this water is found to decrease in temperature and increase in salinity towards the west. At a subsurface depth of about 100 m, a distinct development of cold water takes place especially to the west of longitude 180°.

It is very possible that this warm fresh water comes from the Gulf of Alaska. The northern branch of the easterly currents of the North Pacific bends into the Gulf; there it is submitted to heating and dilution by fresh water of the Gulf, after which it returns towards the west on the southern side of the Aleutian Islands (Sverdrup, 1944). It is clearly shown in the "Current Chart of the North Pacific" compiled by the Hydrographic Office of Japan in 1936 that this branch continues towards the west as far as to the west of longitude 180°. This westward current spreads several branches into the Bering through the Aleutian Chain (Barnes & Thompson, 1938). North of the ridge near Bogoslof Island, currents which are parallel to the ridge towards the east, swing north following the bottom contours of the continental shelf (Barnes & Thompson, 1938). Thus there is found in the Bering at station 24 of the 1954 cruise a practically identical water to that of the warm current to the south of the Aleutian Islands (fig. 13).

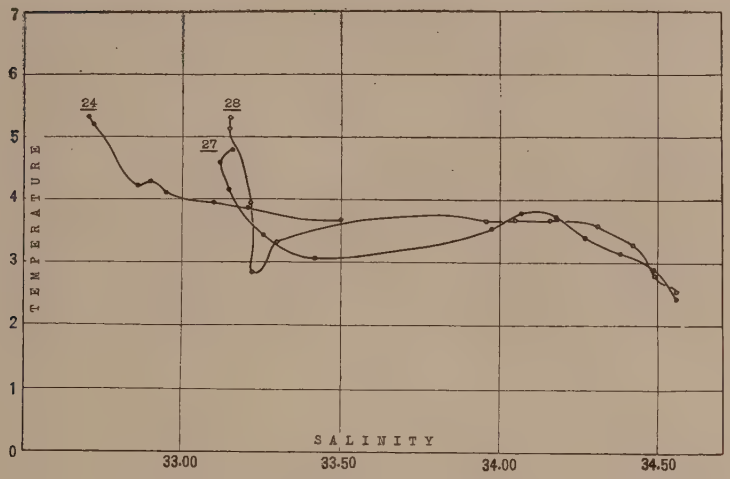

Fig. 13. T–S curves at station 24 to the north of Akutan Island and at stations 27 and 28 to the south of latitude 50° north in the Pacific in 1954

The character of the cold water mass which protrudes from west to east along the southern border of the warm water just described is represented in figure 14, in which

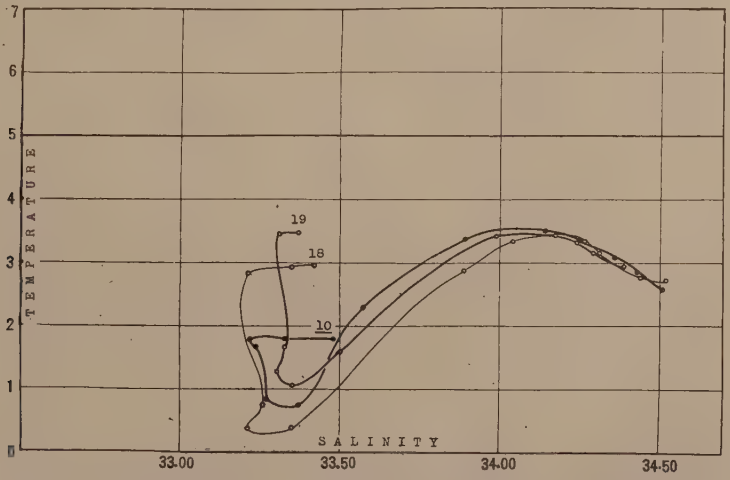

Fig. 14. T–S curves of the cold water of Bering origin obtained in 1953 and 1954

are included T–S diagrams for stations 18 and 19 of the 1953 cruise and for station 10 of the 1954 cruise. That cold water mass has a distinct layer of both minimum

temperature below 1° and minimum salinity below 33.3 ‰ at a level of 100 m, whilst the surface salinity is high being above 33.3 ‰. At deeper levels the temperature is lower by 1 to 2° and the salinity is slightly higher than that of water to the immediately northward.

The source of cold water found in these regions is considered to lie in some area of intensive winter cooling along the Asiatic coast. Barnes & Thompson (1938) have inferred that the Okhotsk Sea, the Gulf of Anadir and the Kamtchatka Peninsula are possible sources. The character of cold water which moves south along the eastern coast of Kamtchatka in the season of present investigation is indicated in T-S diagrams in figure 15, using the data obtained at *Komahashi* station 94 (50-39 N, 159-27 E) on her

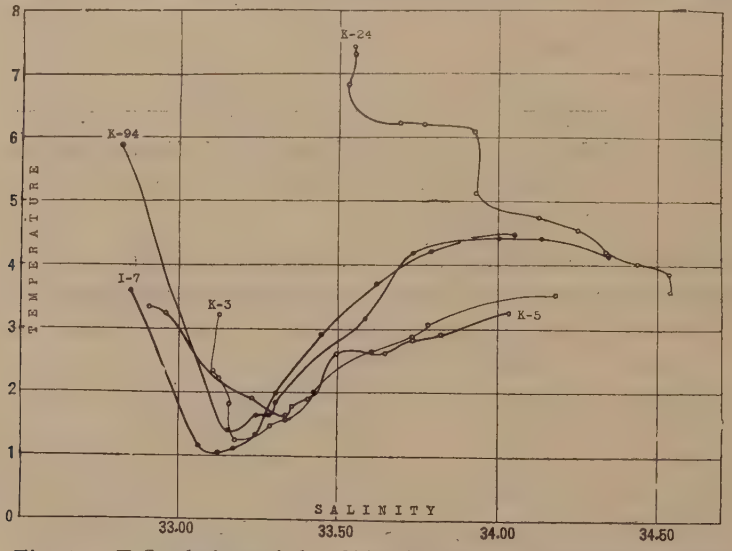

Fig. 15. T-S relations of the Okhotsk water at *Komahashi*-stations 3 and 5 in May 1935 and at *Komahashi*-station 94 in September 1935 and *Itsukushima*-station 7 in July 1935 to the southwest of Kamtchatka. The T-S relations of the Subarctic Water at *Komahashi*-station 24 is also included. Locations of stations are shown in figure 1.

cruise of September 1935 and at *Itsukushima*-station 7 (51-54 N, 159-18 E) on her cruise of July 1935. The T-S diagrams for the Okhotsk water are also included in figure 15 using the data obtained at *Komahashi*-stations 3 (50-45 N, 153-16 E) and 5 (48-39 N, 150-55 E) on her cruise of May 1935. The locations of these stations are indicated in figure 1. Shallow waters in these regions are practically alike, but the deep water below 100 m level in the Okhotsk is distinctly lower in temperature as well as in salinity than that it is off the Kamtchatka Peninsula, and the latter is very much the same as

the deep water at stations 18 and 19 of the 1953 cruise and at station 10 of the 1954 cruise. Shallow water of these stations of the present cruises is a little higher in salinity than that of the two cold regions, and it is probably due to the mixing with the Subarctic Water near the surface. The T–S diagram for the Subarctic Water which flows towards the east or northeast just to the south of this cold water is likewise given in figure 15, using also the materials obtained at *Komahashi*-station 24 (43–34 N, 162–14 E) on her cruise of June 1935.

Thus, it may be said that the cold fresh water found stretching towards the east to form a very narrow belt in latitude 50° north originates mostly in the shallow region along the Siberian coast in the Bering and that it moves southward along the coast of Kamtchatka. A branch of this current bends east from the southern end of that peninsula and flows along the Aleutian Ridge. Another branch moves further south or southwest along the Kurile Islands. The latter branch, mixed with the cold water of the Okhotsk Sea which has poured into the Pacific through the Kurile Chain, meets there the warm extension of the Kuroshiwo Current (Subarctic Water), and is deflected sharply northeast to rejoin the former branch. This narrow belt, stretching towards the east, can be traced as far as longitude 170° west by the characteristic development of the subsurface cold layer found at *Itsukushima*-stations 31 (50–57 N, 169–14 W) and 32 (50–37 N, 169–14 W) in her cruise of July 1935 (fig. 16).

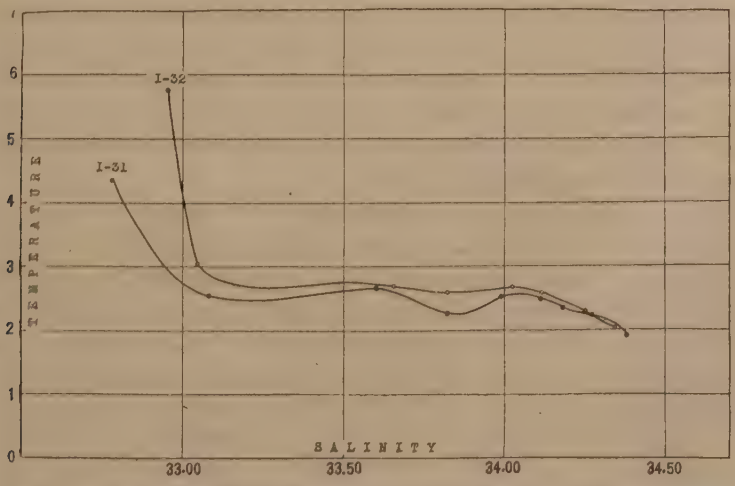

Fig. 16. T–S curves of the continuation of the narrow tongue protruded from west to east to the immediately north of the Subarctic Water; the materials taken at *Itsukushima*-stations 31 and 32. Locations of stations are shown in figure 1.

The water found at stations 1 to 5 of the 1954 cruise has a little different character; typical T–S relation for this water is shown in figure 17 which containes T–S diagram

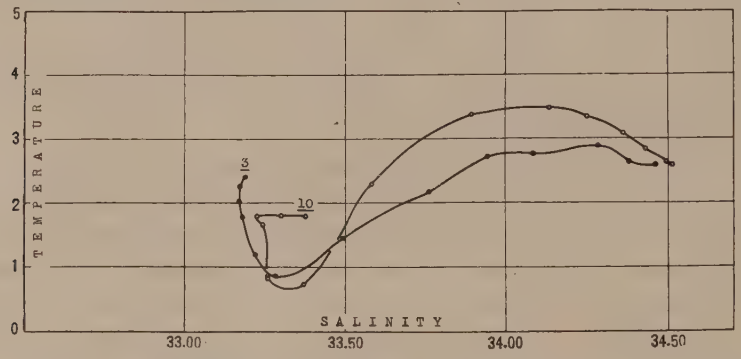

Fig. 17. T–S diagram of the water of Okhotsk origin to the south of the southern Kurile Islands (3). T–S diagrams of the water of Bering origin (10) is also included for comparison.

for station 3. In the same figure is included the T–S diagram for station 10 for comparison. The water at station 3 is apparently lower in temperature as well as in salinity than the water at station 10 especially at deep levels below 100 m, and it is more alike to the water of Okhotsk origin than to the water of Bering origin. Thus, in the southwestern area of the 1954 cruise is found a water mass which probably originates dominantly in the Okhotsk Sea. At several stations, however, the dominant origin of each water cannot be determined from the point of T–S character only, which suggests that an intensive mixing process takes place in this area among the waters from the Bering Sea, Okhotsk Sea and the Subarctic Water.

Water found at statations 1, 3, 13 and 20 in the 1953 cruise and at stations 11, 12, 13, 27 and 28 in the 1954 cruise are mixtures in various proportions of the two dominant water masses; the cold water mass from the west as typically characterized by the T–S diagrams for stations 18 and 10, whilst the warm water mass from the east as typically characterized by the T–S diagrams for stations 4 and 26. In figures 18 and 19 are shown the T–S relations for some stations of this mixed character. The water at station 2 is formed on the border between the cold water from the west and the Subarctic Water (fig. 20).

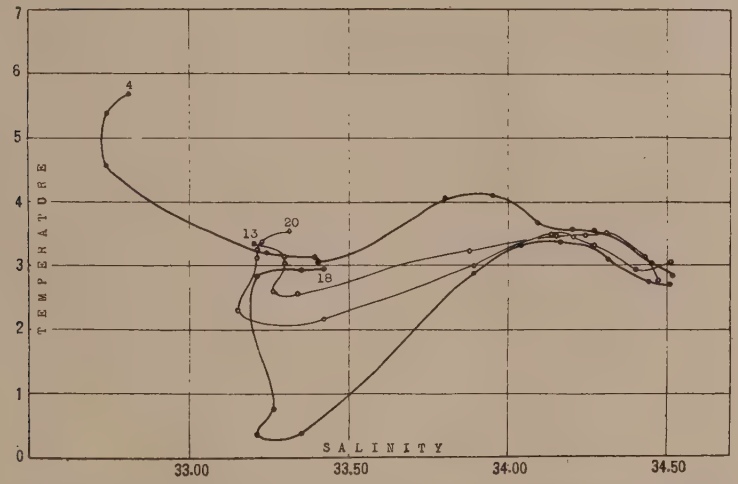

Fig. 18. T-S diagrams of the waters formed by mixing of two dominant water masses; the warm water from the east (4) and the cold water from the west (18), in 1953

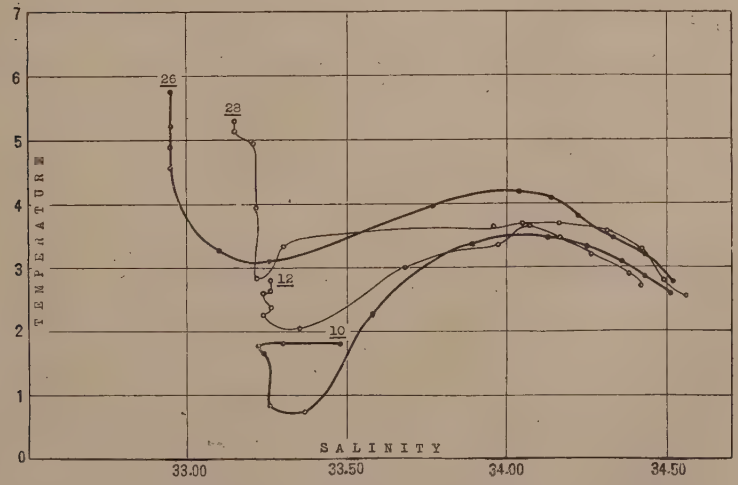

Fig. 19. T-S diagrams of the waters formed by mixing of two dominant water masses; the warm water from the east (26) and the cold water from the west (10), in 1954

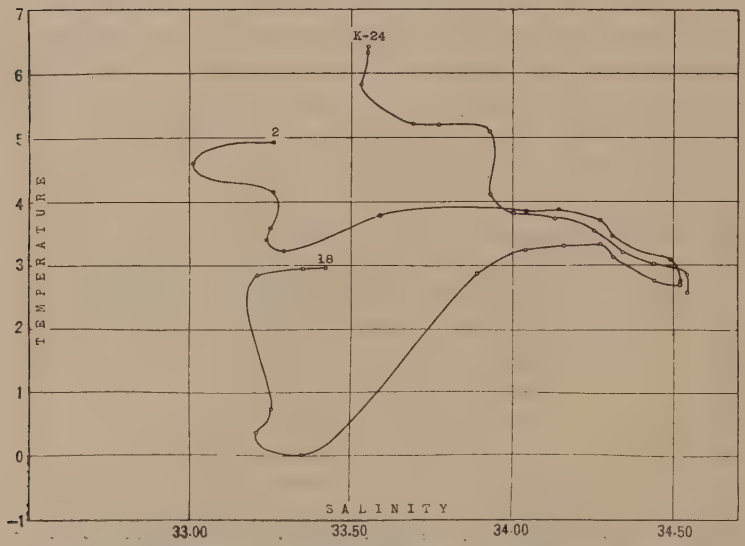

Fig. 20. T–S relation of the water formed on the border between the Subarctic Water (K–24) and the cold water of Bering origin(18)

North of the Aleutian Ridge near Attu, the character of the water is practically identical with that of the water just to the south of the ridge, indicating a northward flow of the Pacific water into the Bering through the shallow channels between Attu and Kiska Islands (in 1953 and 1954) and through the eastern part of the channel between Attu and the Komandorskie Islands (in 1954) (figs. 21 and 12). The shallow layer

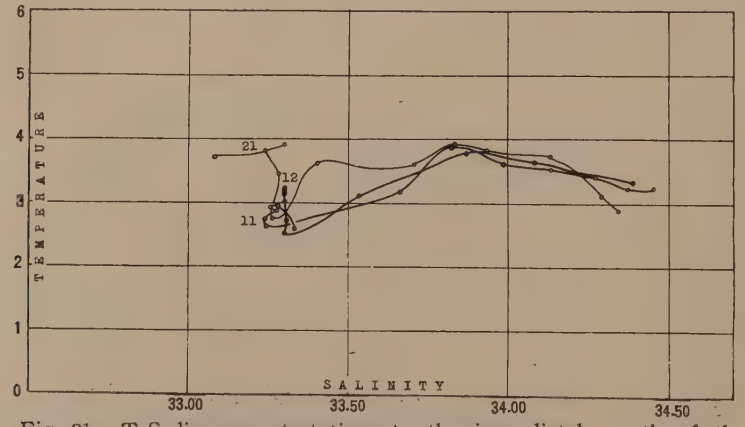

Fig. 21. T–S diagrams at stations to the immediately north of the Aleutian Islands in the Bering. T–S diagram at station 21 to the south of the Aleutian Islands in the Pacific is also included for comparison.

for stations 11 and 12, however, lacks such a marked stratification as found at station 21 in the Pacific and has a uniform vertical distribution of temperature and salinity, probably suggesting that the water from the Pacific suffers some agitation while passing through the shallow channel (fig. 21). The deep water below 100 m for stations located to the north of the ridge is somewhat higher in temperature and lower in salinity than the deep water found to the south of the ridge (figs. 12 and 21); this indicates that there occurs a downward transport of the shallow water which has entered into the Bering from the Pacific, after passing through the channels, as described above.

At stations 6 and 8 of the 1953 cruise and station 16 of the 1954 cruise, all of which are located to the west of the Bowers Bank, it is found that surface layers have high salinity above 33.5 ‰ in 1953 and above 33.3 ‰ in 1954 (fig. 22). Moreover, the

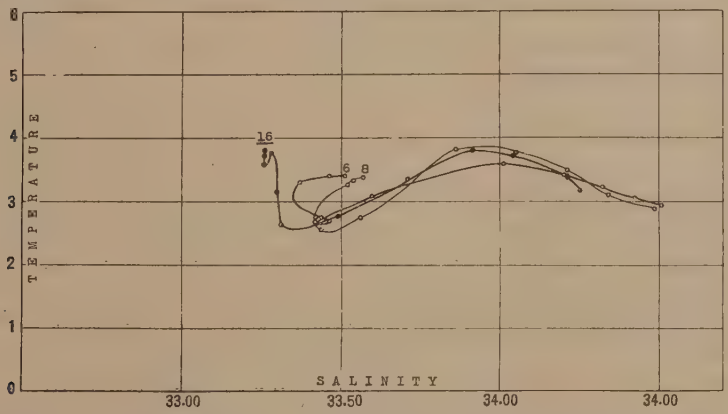

Fig. 22. T-S relations at stations to the east of the Bowers Bank in the Bering

surface salinity as well as surface temperature generally increases towards the east except at station 19 where the surface salinity is below 33.2 ‰ (fig. 23); at station 20 a homogeneous surface layer of 33.39 ‰ in salinity is met with in the 1954 cruise (fig. 24). The deep water at stations 20 and 21 is distinctly higher in salinity than at other stations in the Bering (fig. 24); therefore, it can not be considered to have come from the Pacific through any of the shallow channels between the Aleutian Islands though it is very similar in character to the Subarctic Water. Sverdrup *et al.* (1942) have shown that the temperature and salinity structures of the Bering basin below 100 m are very similar to those in the Subarctic region of the North Pacific. The character of the water in the deep portions of the Bering is shown in figure 24, using the materials obtained at *Dalinevastochinik* station 68 (58-59 N, 174-24 E) in her cruise of September 1932 and *Komahashi*-station 67 (57-20 N, 176-26 E) in her cruise of August 1936. The deep

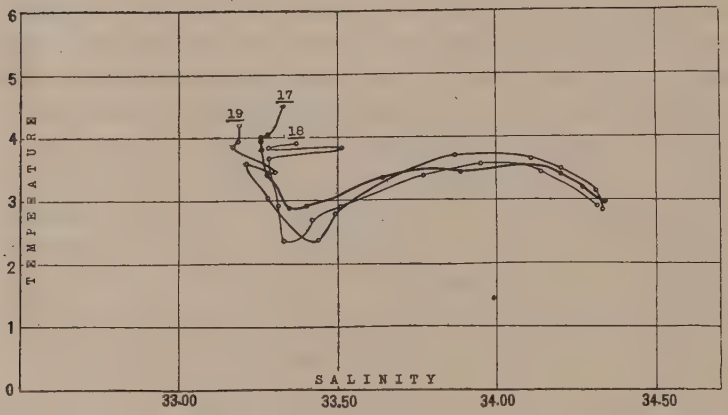

Fig. 23. T-S relations at stations to the west of the Bowers Bank in the Bering

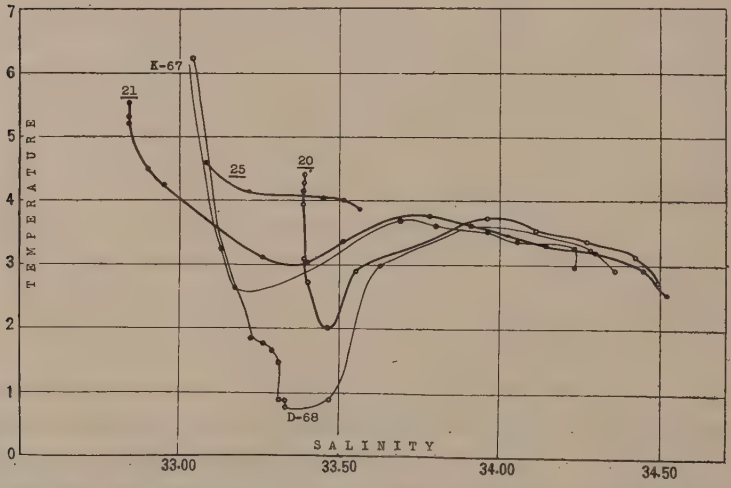

Fig. 24. T-S diagrams at stations off the continental shelf of Bristol Bay in the Bering. T-S relations of the Bering basin water at *Komahashi*-station 67 in August 1936 and *Dalineva-stochinik*-station 68 in September 1932 are also shown. Locations of stations are shown in figure 1.

water at stations 20 and 21 is similar to that of the Bering basin but is still slightly higher in salinity. In this area, an accumulation of more dense water than in the adjacent area has been met with as ascertained by several data obtained in the previous cruises of *Komahashi* and *Chelan*. The T-S relations below 100 m level for

Komahashi-stations D (53-54 N, 172-38 W) and F (55-50 N, 176-10 W) in her cruise of August 1934 and for *Chelan*-stations 106 (54-22 N, 168-17 W) and 107 (55-04 N, 168-49 W) in her cruise of August 1933, are similar to that for stations 20 and 21; furthermore, these waters are more dense than the surrounding water as characterized by T-S diagrams for *Komahashi*-stations C (53-29 N, 175-26 W) and E (56-14 N, 171040 W) and for *Chelan*-station 102 (53-57 N, 167-52 W) (fig. 25). This accumulation of dense water

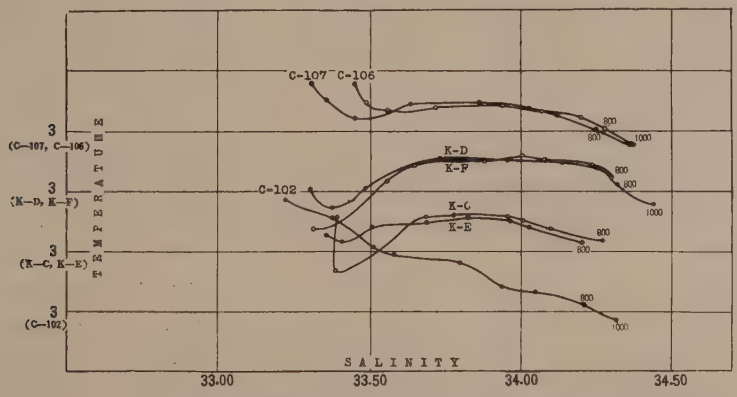

Fig. 25. T-S diagrams below 100 m at a number of *Komahashi* and *Chelan*-stations to the east of the Bowers Bank. Locations of stations are shown in figure 1.

suggests the occurence of a large counter-clockwise eddy as discussed below, and the high salinity of the deep water in this area is probably due to the upwelling of the deeper water caused by the eddy motion.

The water at station 19 is considered to belong to the Bering basin water especially for its low surface salinity, while the remarkably high salinity of the shallow layers at station 20 is considered to be of Pacific origin. The surfacce layer of the Subarctictic Water which has high salinity above 33.5 ‰ is probably carried from the Pacific into the Bering probably through the channel between Attu and the Komandorskie Islands and then flows east along the northern side of the Aleutian Islands. The T-S curves at stations 6 and 8 of the 1953 cruise and at stations 16, 17, 18 and 19 of the 1954 cruise show complicated and irregular fluctuations of salinity value in shallow layers for each station (fig. 23), which may indicate the advance of mixing process of the Subarctic Water with the water of the Bering basin or with the water which has come from the Gulf of Alaska and entered into the Bering through some of the channels between the Aleutian Islands. The water at station 25 is high in salinity and is considered to belong to the same water as that at station 20 (fig. 24). The inflow of the Subarctic Water of the North Pacific into the Bering, however, can not be found in the present observations; probably it is of intermittent character because the surface water at

Chelan–stations 106 and 107 and *Komahashi*–stations D and F never shows higher salinity than 33.0 ‰ in the respective year.

The surface salinity decreases from station 21 eastward to Bristol Bay where the values are below 32 ‰, indicating that the runoff from the large Alaskan rivers stretches far west to station 21.

V. Current

Something has been said about the prominent features of the currents in the present regions. A discussion follows on the currents based on the charts showing the topography and profiles of the isobaric surfaces.

In figure 26 is shown the dynamic topography of the isobaric surfaces 100-decibar relative to the 750-decibar surface by means of the data obtained on the 1953 cruise. When preparing this figure, the courses of the isotherms and isohalines are taken into consideration.

The northern branch of the Kuroshiwo Extension is found to flow northeast to the south of station 2. To the north of latitude 50° north, a westerly current carries warm water of low salinity which is slightly deflected south to the south of Kiska Island, swings north at about longitude 170° east, and then returns to the east to the south of Attu Island, forming thus a large clockwise eddy with its center at station 21. It is then swung north and the major part of that mass of water passes through the channel between Attu and Kiska Islands into the Bering, while the minor part seems to pass over the ridge to the west of Attu Island.

Between the Aleutian Current and this westerly current in the Pacific, a narrow belt of low temperature stretches from west to east which can be traced as far as longitude 170° west as mentioned above.

In the Bering Sea, the water from the Pacific moves towards the east along the Aleutian Islands but is soon deflected towards the Islands partly on account of the thrusting out of the cold water of the Bering basin at station 8 and partly following the bottom contours of the Bowers Bank. It turns again to the east and then to the northeast passing between stations 5 and 6, and flows into the western Hemisphere.

The profiles of the isobaric surfaces in Section I are represented in figure 27. The westerly current in the Pacific shows a velocity which, at the surface, is 4 cm/sec between stations 3 and 4, decreases with increasing depth, until at 500 m level the westward velocity is below 0.5 cm/sec. The easterly current between stations 2 and 3 has a velocity of 3 cm/sec at the surface and at 200 m level it practically disappears. The westerly current in the Gulf of Alaska was calculated 7 cm/sec at the surface (Sverdrup, 1944) with reference to 2000-decibar surface, but the current value obtained on the *Komahashi* cruise in 1935 by the current meters in two layers (10 m and 500 m) was 0.3 knot to the

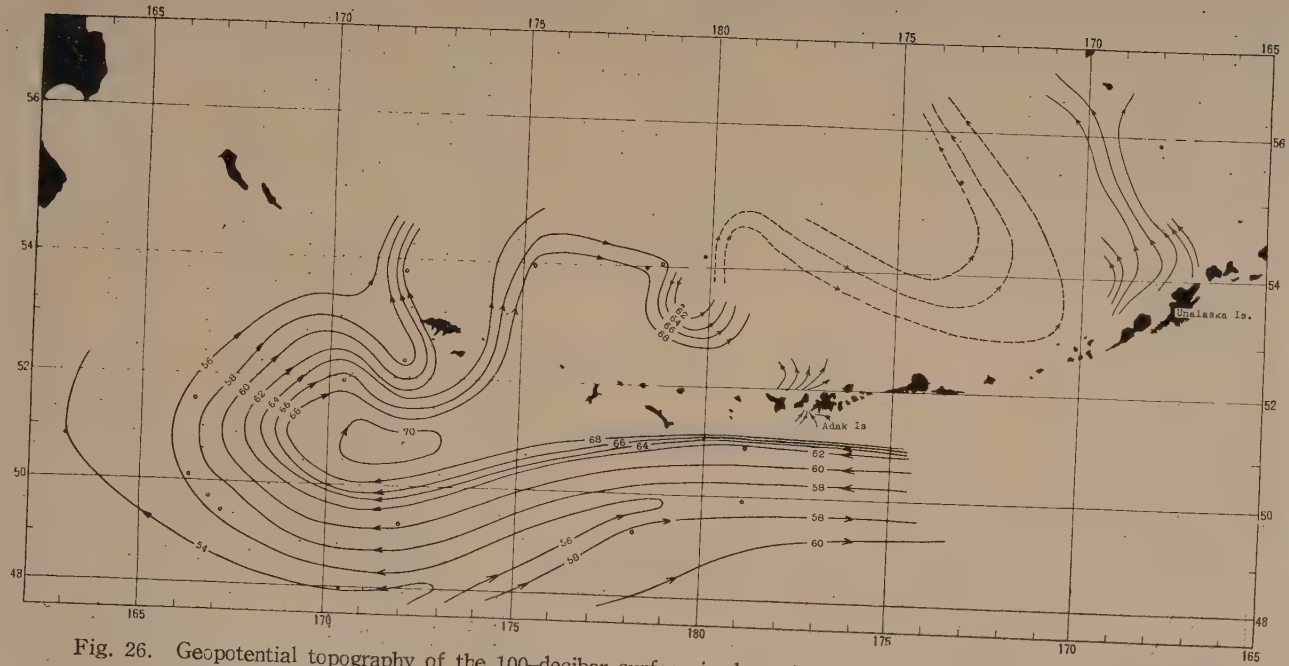

Fig. 26. Geopotential topography of the 100-decibar surface in dynamic centimeters referred to the 750-decibar surface according to the observation on May 14 to June 6, 1953

The broken lines show schematically the currents in the area to the east of the Bowers Bank in the Bering according to the observation on May 26 to June 8, 1954. Near Adak Island and to the north of Unalaska Island, directions of flow are shown schematically according to the observations on *Gannet* in June 1933 and *Chelan* in August 1934 (Barnes & Thompson, 1938).

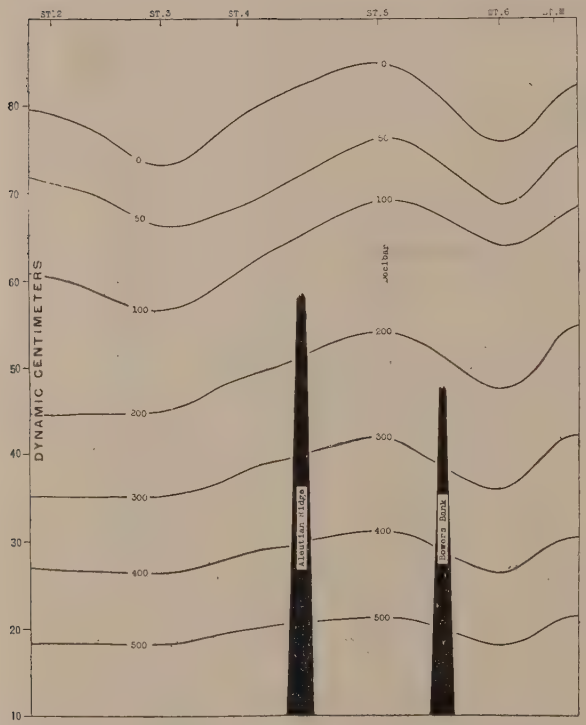

Fig. 27. Profiles of isobaric surfaces in dynamic centimeters referred to the 750-decibar surface in Section I on May 15 to 18, 1953

south of the Aleutian Islands in longitude 180°. The velocities of this westerly current shown in the "Current Chart of the North Pacific" vary from 0.3 to 0.5 knot. These values are higher than are found on the present observations suggesting that the prevailing winds exert some effect on the surface layers as well as that the water at a depth of 750 m is not at rest as supposed in the present writers' computation.*

Between stations 5 and 6, is found a northerly current which has velocities of 5 cm/sec at the surface and of 2 cm/sec at 500 m level. Between stations 6 and 8, the Bering basin water thrusts out, the velocity of which is 6 cm/sec at the surface and increases slightly with increasing depth reaching 8 cm/sec at 200 m level. Below this level, the velocities decrease with increasing depth until at 500 m level the value is 3 cm/sec.

The profiles of the isobaric surfaces in Section II are represented in figure 28. The westerly current between stations 20 and 21 is a little more accelerated than in Section I and the velocity which, at the surface, is 6 cm/sec, decreases with increasing depth especially rapidly below 200 m. The returning flow between stations 21 and 13 has a higher velocity of 7 cm/sec at the surface which also decreases but slightly with depth down to a level of 100 m; below this level it decreases rapidly. At 500 m level the waters are practically motionless.

In figure 29 is represented the profiles of the isobaric surfaces with reference to 800-decibar level in the whole section of the 1954 cruise. The broken lines in the figure

* Taguchi & Hirose (1954) have measured a high velocity of about 2 knots to the south of Kiska Island in May 1953 by current meters in two layers (10 m and 500 m) in the boundary area between the water of low transparency to the north and the water of high transparency to the south.

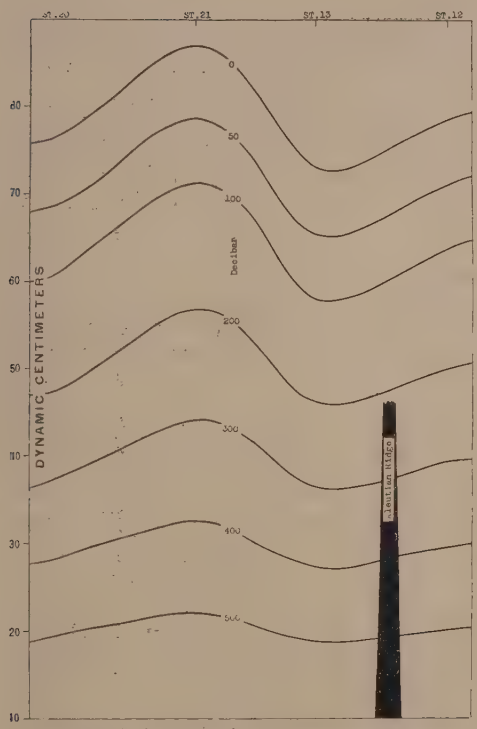

Fig. 28. Profiles of isobaric surfaces in dynamic centimeters referred to the 750-decibar surface in Section II on May 20 to June 6, 1953

indicate the axises of no motion normal to the section. In the central part of the section, the general features of currents are prctically identical to those in the preceding year. The current which enters the Bering from the Pacific between stations 13 and 14 has a velocity of 4 cm/sec at the surface which is of the same order as found between stations 3 and 4 in 1953. At station 16, in the Bering, a thrusting out of the Bering basin water towards the south is met with in this year also, but in a more weak current than in the preceding year. Between stations 7 and 10, is found a slight horizontal undulation of the currents which probably indicates a minor development of eddy motion on the boundary between the warm water from the Gulf of Alaska and the cold water from the Bering.

In the southwestern part of the section, there is found a remarkable horizontal undulation of the water passing in and out of the vertical plane of the section, indicating the development of successive whirls between the cold water from the Okhotsk and the warm water of the Kuroshiwo Extension. The current velocity, however, does not exceed 3 cm/sec at the surface and decreases with increasing depth.

To the east of the Bowers Bank in the Bering the flows of water are generally slow except in the easternmost region to the east of station 20 where is found a northward current of high velocity of 8 cm/sec at the surface. Between stations 17 and 20, the southerly inflow of the Bering basin water is found, while to the west of station 17 there is a northerly current. The water of the latter current is considered to be composed mainly of the waters from the Pacific; one part may come through the channels of the Aleutian Islands to the west of longitude 180° and flows east and then northeast between stations 5 and 6 of the 1953 cruise, and the other part may come through the Tanaga or Amchitka Passes and flow northward (Barnes & Thompson, 1938).

Thus, there are found two successive eddies to the west of the Bowers Bank. One

of them rotates clockwise with its center in the vicinity of station 17 at the surface. The same eddy was found in the USS Nereus cruise in the summer of 1947 (LaFond & Pritchard, 1952). The axis of rotation of this eddy seems to be extremely oblique especially below 300 m level as seen in the figure; at the surface it lies at station 17, while at a depth of 600 m it lies at station 19. The other is a counter-clockwise circulation of water with its center at station 20, the axis of which seems also to be slightly oblique. In figure 26 the currents of the regions to the east of the Bowers Bank are shown schematically.

VI. Summary

1. The hydrographic work performed on two cruises made during the early summers of 1953 and 1954 to the vicinity of the Aleutian Islands and the southern part of the Bering Sea has been outlined.

2. Along the southern side of the Aleutian Islands, a warm water mass of low salinity is found to flow from east to west. It reaches as far west as longitude 165° east, on its way spreading several branches into the Bering through the shallow channels between the Aleutian Islands, then it swings north or northeast into the Bering from the Pacific passing over the Aleutian Ridge near Attu Island. A large clockwise eddy of this warm water is, thus, formed to the south or southwest of Attu Island.

3. Between this warm water and the Kuroshiwo Extension or Aleutian Current an abnormally cold water of low salinity is found to flow westward, forming a very narrow tongue. It originates principally from the Bering, probably from the Gulf of Anadir, and then moves along the eastern coast of Kamtchatka. It is then deflected east or northeast off the Kurile Islands and flows east along the Aleutian Islands in latitude 50° north.

4. Off the southern islands of the Kuriles, another cold water of low salinity is found which originates from the Okhotsk Sea as distinguished from the water of Bering origin by the lower temperature of deep water below 100 m level.

5. In the Bering Sea, waters from the Pacific set east just to the north of the Aleutian Islands. The salinities of the southern Bering are of lower values than in the Pacific indicating the occurrence of a downward transport of the shallow water which has poured into the Bering form the Pacific.

6. The Bering basin water thrusts south or southeast especially to the east of the Bowers Bank, while the fresh water of Bristol Bay moves north. Thus, two successive whirls, one clockwise and another counter-clockwise, develop to the east of the Bowers Bank.

7. Stratification of water consisting of an upper layer of relatively cold water of low salinity resting on a warm and saline water, is found at most of the stations. The most conspicuous features of stratification are the existence of a subsurface layer of cold water of low salinity at about 100 m depth and an intermediate layer of maximum

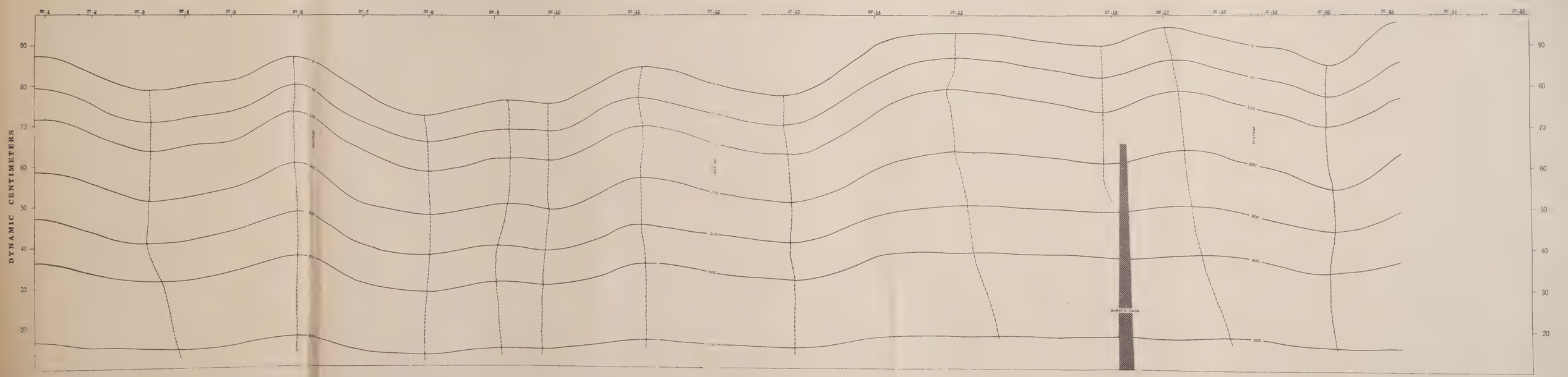

Figure 29. Profiles of isobaric surfaces in dynamic centimeters referred to the 800 decibar surface in the whole section covered on May 26 to June 8 by the 1954 cruise Broken lines show the axises of no motion normal to the section.

temperature at about 300 m depth. The cause of such stratification in these regions is mainly the advection of the severely cold and fresh water from the Asiatic coast of the Bering Sea spreading over waters of greater density from the Pacific.

8. The current velocities calculated from the inclinations of isobaric surfaces are below 10 cm/sec everywhere; they are in most cases greatest at the surface.

References

Barnes, C. A. & Thompson, T. G. (1938). Physical and chemical investigations in Bering Sea and portions of the North Pacific Ocean. *Univ. Wash. Pub. Oceanogr.* 3 (2), 243p.

Hydrographic Office of Japan (1937). [Hydrography of the northern North Pacific and adjacent seas in summer seasons of 1934 to 1936.] *Hydrographic Bull.* No. 3.

LaFond, E. C. & Pritchard, D. W. (1952). Physical oceanographic investigations in the eastern Bering and Chukchi Seas during the summer of 1947. *Journ. Mar. Res.* 11 (1), 69–86.

Sverdrup, H. U., Johnson, M. W. & Fleming, R. H. (1942). *The oceans.* New York, Prentice-Hall Inc. 1087p.

Sverdrup, H. U. (1944). Result in physical oceanography. *Sci. Results Cruise VII Carnegie during 1928–1928, Oceanography* I-A, 83-110.

Taguchi, K. & Hirose, H. (1954).[Surface currents and oceanographical condition in the northern Pacific salmon fishing ground.] *Bull. Jap. Soc. Sci. Fish.* 20 (7), 576–50.

Uda, M. (1935). [On the distribution, origin and movement of the intermediate cold layer in the northwestern Pacific.] *Umi to Sora* 15 (12), 445–452.

Watanabe, N. *et al.* (compiled by) (1954). [Hydrographic data in the northern North Pacific and adjacent seas obtained in 1887 to 1953]. Nogyogijutsu-Kyokai. 556p.

Appendix

Observations obtained on the cruise of the "*Oshoro Maru*" in 1953

Station	1		2		3		4		5	
Lat. Long.	49. 22 N 178. 18 E		48. 57 N 178. 49 W		50. 00 N 178. 44 W		50. 58 N 178. 40 W		52. 36 N 178. 46 W	
Date	V — 14		V — 15		V — 15		V — 16		V — 17	
Time	20.00— 1.15		13.45—16.15		23.40— 2.00		8.35—10.25		1.20— 3.00	
	Temperature	Salinity	Temperature	Salinity	Temperature	Salinity	Temperature	Salinity	Temperature	Salinity
0	4.25	33.22	4.90	33.26	4.58	33.20	5.68	32.81	4.76	33.24
10	4.23	33.19	4.59	33.01	4.22	33.05	5.39	32.74	4.64	33.15
25	3.50	33.10	4.14	33.26	3.43	32.97	4.57	32.74	4.15	33.21
50	3.30		3.59	33.25	3.21	33.26	3.20	33.24	3.76	33.35
75	3.24	33.17	3.40	33.24	3.16	33.26	3.14	33.39	3.66	33.42
100	3.14	33.24	3.24	33.29	2.92	33.28	3.06	33.40	3.66	33.42
150	3.73	33.91	3.79	33.69	3.95	33.91	4.05	33.80	3.23	33.19
200	3.77	34.02	3.84	34.04	3.87	34.05	4.11	33.95	3.25	33.63
300	3.74	34.17	3.85	34.14	3.72	34.23	3.66	34.09	3.35	33.87
400	3.58	34.26	3.71	34.27	3.50	34.28	3.57	34.20	3.50	34.01
500	3.44	34.32	3.44	34.31	3.40	34.35	3.54	34.27	3.55	34.15
750	2.94	34.40	3.08	34.49	2.98	34.41	3.12	34.43	3.12	34.37
1000	2.63	34.59	2.74	34.51	9.23	34.53	2.84	34.52	2.87	34.48

Station	6		8		10		11		12	
Lat. Long.	53. 22 N 179. 27 E		54. 00 N 178. 57 E		53. 50 N 175. 24 E		53. 35 N 173. 43 E		53. 42 N 172. 09 E	
Date	V — 17		V — 18		V — 19		V — 19		V — 20	
Time	13.20—14.45		7.30— 8.30		9.30—10.30		19.20—20.50		5.20— 7.00	
	Temperature	Salinity	Temperature	Salinity	Temperature	Salinity	Temperature	Salinity	Temperature	Salinity
0	3.40	33.51	3.38	33.57	3.44	33.55	2.58	33.33	3.19	33.30
10	3.38	33.46	3.35	33.54	3.43	33.40	2.95	33.28	3.17	33.30
25	3.30	33.37	3.27	33.52	3.25	33.08	2.94	33.26	3.13	33.30
50	2.82		2.74	33.42	2.93	33.22	2.92	33.28	3.03	33.30
75	2.75	33.43	2.69				2.75	33.24	2.74	33.31
100	2.70	33.47	2.55	33.44			2.64	33.24	2.51	33.30
150	2.69	33.42	2.73	33.56			3.18	33.66	3.08	33.53
200	3.08	33.60	3.00	33.70			3.91	33.82	3.78	33.87
300	3.58	34.01	3.86	33.86			3.62	33.98	3.64	34.08
400	3.38	34.21	3.56	34.05			3.52	34.13	3.52	34.14
500	3.21	34.32	3.50	34.21			3.42	34.27	3.50	34.20
750	3.00	34.46	3.10	34.34			3.25	34.37	3.13	34.46
1000	2.86	34.52	2.90	34.50					2.92	34.49

Station	13		14		15		16		17	
Lat. Long.	52. 15 N 172. 07 E		49. 55 N 160. 15 E		49. 33 N 167. 01 E		50. 09 N 166. 14 E		51. 28 N 166. 24 E	
Date	V — 20		V — 21		V — 24		V — 25		V — 27	
Time	19.10—21.00		17.30—18.30		13.00—14.10		16.00—18.00		14.30—16.00	
	Tem-perature	Salinity	Tem-perature	Salinity	Tem-perature	Salinity	Tem-peraturs	Salinity	Tem-perarure	Salinity
0	3.20	33.55	4.30	33.31	3.60	33.30	4.35	33.15	4.28	33.30
10	3.13	33.30	3.59	33.26	3.59	33.28	3.58	33.30	4.27	33.30
25	3.04	33.30	3.49	33.26	3.42	33.31	3.01	33.28	3.78	33.26
50	3.10	33.30	3.29	33.28	2.13	32.83	2.10	33.30	2.79	33.23
75	2.60	33.26	2.92	33.21	1.46	33.30	1.98	33.22	2.57	33.26
100	2.56	33.34	2.82	33.30	1.50	33.06	1.92	33.26	2.33	33.26
150	3.25	33.88	2.94	33.48	3.13	33.77			2.55	33.72
200	3.04	33.90	3.82	33.87	3.30	34.02			3.23	33.96
300	3.48	34.15	3.82	34.02	3.35	34.19			3.38	34.21
400	3.48	34.24	3.64	34.12	3.29	34.28			3.45	34.26
500	3.51	34.31	3.55	34.18	3.17	34.33			3.45	34.34
750	3.05	34.45	3.19	34.33	2.75	34.42			2.78	34.48
1000	2.50	34.50	2.75	34.40						

Station	18		19		20		21	
Lat. Long.	50. 55 N 161. 23 E		49. 50 N 166. 46 E		49. 24 N 172. 00 E		50. 51 N 172. 00 E	
Date	VI — 1		VI — 2		VI — 5		VI — 6	
Time	8.00—10.00		20.00—22.00		13.00—15.30		12.00—14.00	
	Tem-perature	Salinity	Tem-perature	Salinity	Tem-perature	Salinity	Tem-perature	Salinity
0	2.96	33.42	3.50		3.55	33.31	3.90	33.30
10	2.95	33.35	3.48	33.37	3.36	33.22	3.72	33.08
25	2.85	33.21	3.45	33.31	3.28	33.21	3.84	33.24
50	0.75	33.26	1.66	33.33	3.20	33.35	3.45	33.28
75	0.38	33.21	1.26	33.30	3.15	33.21	3.46	33.26
100	0.01	33.35	1.06	33.35	2.30	33.15	2.76	33.26
150	2.88	33.89	1.60	33.50	2.18	33.42	3.62	33.40
200	3.34	34.04	3.44	33.99	3.01	33.89	3.60	33.70
300	3.42	34.16	3.41	34.17	3.49	34.13	3.94	33.83
400	3.34	34.27	3.30	34.24	3.46	34.20	3.84	33.93
500	3.13	34.31	3.13	34.29	3.30	34.26	3.73	34.13
750	2.76	34.44	2.45	34.46	2.94	34.40	3.11	34.29
1000	2.72	34.53			3.08	34.52	2.86	34.34

Observations obtained on the cruise of the "*Oshoro Maru*" in 1954

Station	1		2		3		4		5	
Lat. Long.	42. 15 N 145. 41 E		42. 43 N 147. 21 E		43. 23 N 148. 51 E		44. 12 N 150. 38 E		45. 04 N 152. 23 E	
Date	V — 26		V — 27		V — 27		V — 28		V — 28	
Time	17.20—18.50		05.00—06.30		7.00—18.08		5.00— 6.00		7.00—18.15	
	Tem-perature	Salinity	Tem-perature	Salinity	Tem-perature	Salinity	Tem-perature	Salinity	Tem-perature	Salinity
0	4.8	33.14	3.4	33.17	2.4	33.19	2.5	33.15	2.6	33.21
10	4.84	33.15	3.35	33.15	2.27	33.17	2.30	33.17	2.28	33.17
25	3.78	33.30	2.46	33.21	2.02	33.17	2.34	33.15	2.02	33.17
50	3.26	33.30	1.79	33.21	1.79	33.18	1.66	33.21	1.82	33.21
75	2.36	33.30	1.35	33.26	1.17	33.22	1.22	33.22	1.14	33.22
100	1.91	33.25	1.13	33.26	0.86	33.28	1.06	33.22	1.46	33.38
150	0.74	33.39	0.80	33.43	1.45	33.49	1.01	33.44	1.18	33.57
200	1.41	33.52	1.10	33.49	2.19	33.76	2.07	33.65	1.79	33.76
300	2.46	33.78	1.71	33.68	2.71	33.94	2.96	33.94	2.54	33.85
400	2.88	33.91	2.96	33.97	2.77	34.08	3.13	34.12	2.92	34.00
600	2.99	34.14	2.97	34.23	2.89	34.28	2.90	34.28	2.94	34.24
800	2.80	34.33	2.83	34.38	2.65	34.38	2.65	34.45	2.80	34.37
1000	2.68	34.33	2.68	34.45	2.58	34.46	2.41	34.47	2.52	34.59

Station	6		7		8		9		10	
Lat. Long.	45. 59 N 154. 16 E		46. 52 N 156. 02 E		47. 49 N 157. 59 E		48. 39 N 160. 07 E		49. 25 N 162. 12 E	
Date	V — 29		V — 29		V — 30		V — 30		V — 31	
Time	5.00— 6.05		17.00—18.00		15.00— 6.58		16.40—17.40		4.05— 5.00	
	Tem-perature	Salinity	Tem-perature	Salinity	Tem-perature	Salinity	Tem-perature	Salinity	Tem-perature	Salinity
0	2.0	33.33	1.6	33.21	1.7	33.28	1.5	33.30	1.8	33.30
10	1.89	33.44	1.41	33.21	1.59	33.24	1.41	33.22	1.79	33.48
25	1.87	33.30	1.36	33.21	1.64	33.24	1.45	33.24	1.78	33.22
50	1.65	33.30	1.28	33.21	1.49	33.26	1.38	33.24	1.66	33.24
75	1.57	33.30	1.17	33.21	1.20	33.30	1.31	33.26	0.84	33.26
100	1.17	33.46	0.74	33.22	1.02	33.27	1.06	33.24	0.75	33.37
150	0.64	33.36	1.15	33.44	2.73	33.86	2.14	33.70	2.28	33.58
200	0.83	33.38	2.64	33.77	3.44	34.03	3.15	33.95	3.37	33.89
300	2.05	33.74	3.30	34.07	3.45	34.15	3.48	34.13	3.48	34.13
400	2.38	33.81	3.15	34.16	3.32	34.26	3.32	34.20	3.33	34.25
600	2.77	34.09	2.99	34.34	3.03	34.36	3.00	34.33	3.09	34.36
800	2.87	34.27	2.85	34.46	2.80	34.60	2.80	34.44	2.85	34.43
1000	2.60	34.69	2.71	34.47	2.47	34.69	2.54	34.48	2.58	34.51

Station	11		12		13		14		15	
Lat. Long.	50. 15 N 164. 28 E		51. 03 N 166. 43 E		51. 44 N 168. 43 E		52. 34 N 171. 04 E		53. 14 N 173. 28 E	
Date	V — 31		VI — 1		VI — 1		VI — 2		VI — 2	
Time	16.00—16.55		4.00— 5.00		16.05—17.00		4.00— 4.55		16.00—16.53	
	Tem-perature	Salinity	Tem-perature	Salinity	Tem-perature	Salinity	Tem-perature	Salinity	Tem-perature	Salinity
0	3.3	33.33	2.8	33.26	3.1	33.26	4.2	33.10	4.3	33.13
10	3.17	33.28	2.64	33.26	2.63	33.26	4.12	33.08	3.89	33.12
25	2.97	33.28	2.60	33.24	2.52	33.26	3.95	33.08	3.78	33.15
50	2.82	33.28	2.36	33.26	2.46	33.26	3.85	33.08	3.36	33.13
75	2.34	33.30	2.26	33.24	2.18	33.26	3.34	33.15	3.36	33.17
100	1.98	33.32	2.05	33.35	1.84	33.26	3.01	33.26	2.99	33.26
150	2.22	33.48	2.99	33.68	2.83	33.78	2.66	33.36	3.00	33.15
200	3.54	33.78	3.35	33.97	3.45	34.00	3.72	33.69	3.40	33.46
300	3.82	34.02	3.64	34.07	3.45	34.11	3.95	34.13	3.94	33.84
400	3.64	34.12	3.45	34.15	3.35	34.20	3.83	34.05	3.84	33.98
600	3.41	34.24	3.19	34.26	3.10	34.31	3.58	34.20	3.54	34.16
800	3.07	34.33	2.90	34.38	2.87	34.38	3.31	34.27	3.23	34.25
1000	2.75	34.40	2.70	34.42	2.57	34.43	2.96	34.34	3.11	34.36

Station	16		17		18		19		20	
Lat. Long.	53. 59 N 178. 13 E		54. 19 N 179. 59 E		54. 38 N 177. 54 W		54. 51 N 175. 40 W		55. 06 N 173. 09 W	
Date	VI — 5		VI — 6		VI — 6		VI — 6		VI — 7	
Time	3.00— 4.05		15.00—15.55		3.05— 3.57		15.05—16.10		3.04— 3.55	
	Tem-perature	Salinity	Tem-perature	Salinity	Tem-perature	Salinity	Tem-perature	Salinity	Tem-perature	Salinity
0	3.8	33.26	4.5	33.33	3.9	33.37	4.2	33.19	4.4	33.39
10	3.57	33.26	4.04	33.28	3.69	33.28	3.95	33.19	4.27	33.39
25	3.73	33.26	4.01	33.26	3.84	33.51	3.86	33.17	4.15	33.39
50	3.76	33.28	3.96	33.26	3.74	33.28	3.45	33.30	3.94	33.39
75	3.15	33.30	3.82	33.26	2.92	33.31	3.62	33.21	3.08	33.39
100	2.64	33.31	3.42	33.28	2.36	33.33	3.05	33.28	2.71	33.40
150	2.77	33.49	2.88	33.35	2.68	33.42	2.38	33.44	2.00	33.46
200	3.35	33.71	2.91	33.40	2.90	33.51	2.80	33.49	2.88	33.55
300	3.80	33.91	3.36	33.64	3.40	33.77	3.74	33.87	3.71	33.96
400	3.72	34.04	3.45	33.89	3.56	33.95	3.66	34.11	3.51	34.11
600	3.40	34.20	3.38	34.20	3.45	34.16	3.48	34.20	3.38	34.27
800	3.17	34.25	3.18	34.27	3.14	34.25	3.15	34.31	3.13	34.42
1000			2.95	34.34	2.81	34.34	2.83	34.33	2.71	34.49

Station	21		22		23		24		25	
Lat. Long.	55. 25 N 170. 37 W		55. 46 N 167. 58 W		56. 22 N 165. 16 W		54. 43 N 165. 56 W		52. 43 N 171. 24 W	
Date	VI — 7		VI — 8		VI — 8		VI — 15		VI — 16	
Time	15.00—15.53		2.22— 2.37		14.00—14.10		9.00— 9.48		15.05—15.26	
	Tem-perature	Salinity	Tem-perature	Salinity	Tem-perature	Salinity	Tem-perature	Salinity	Tem-perature	Salinity
0	5.3	32.84	5.3	32.36	5.0	31.74	5.2	32.72	4.6	33.08
10	5.53	32.84	5.35	32.36	5.06	31.91	5.33	32.70	4.15	33.21
25	5.21	32.84	5.15	32.36	0.39	31.91	4.22	32.86	4.61	33.42
50	4.25	32.95	3.74	32.45	−0.76	31.96	4.55	32.90	4.03	33.44
75	4.49	32.90	3.48	32.77			4.15	32.95	4.00	33.51
100	3.10	33.26	3.46	32.95			3.98	33.10	3.86	33.55
150	3.01	33.40					3.59	33.21		
200	3.36	33.51					3.70	33.35		
300	3.75	33.78								
400	3.59	33.91								
600	3.30	34.18								
800	2.93	34.45								
1000	2.54	34.52								

Station	26		27		28	
Lat. Long.	51. 10 N 172. 52 W		49. 47 N 176. 11 E		49. 41 N 171. 16 E	
Date	VI — 17		VI — 19		VI — 20	
Time	8.30— 9.25		13.15—14.10		13.00—14.02	
	Tem-perature	Salinity	Tem-perature	Salinity	Tem-perature	Salinity
0	5.2	32.95	4.8	33.13	5.3	22.15
10	5.72	32.95	4.65		5.14	33.15
25	4.55	32.95	4.60	33.12	4.94	33.21
50	4.89	32.95	4.18	33.15	3.95	33.22
75	3.26	33.10	3.43	33.26	2.82	33.22
100	3.10	33.26	3.06	33.42	3.34	33.30
150	3.96	33.77	3.54	33.98	3.65	33.96
200	4.18	34.04	3.80	34.07	3.67	34.05
300	4.06	34.14	3.71	34.18	3.68	34.16
400	3.80	34.22	3.39	34.27	3.57	34.31
600	3.46	34.33	3.14	34.38	3.27	34.42
800	3.18	34.43	2.87	34.49	2.78	34.49
1000	2.75	34.52	2.44	34.56	2.52	34.56

ACCUMULATION OF ORGANIC MATTER IN MARINE BOTTOM AND ITS OCEANOGRAPHIC ENVIRONMENT IN THE SEA TO THE SOUTHEAST OF HOKKAIDO

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I. Introduction

Organic substances (marine humus) in marine sediments are rather variable in accumulated amount or in chemical properties owing to change of environment of sedimentation. The organic constituents, because of thier greater susceptibility to change with varying conditions of deposition, might prove to be more sensitive indexes of the environmental conditions than the inorganic ones; however, of course, both should be used together in the interpretation of the history of the sedimentation or of the environments.

As to environmental factors relating to the characters of organic matter in sea bottom, there are to be emphasized the oceanographic conditions as well as submarine topography (Kato, 1951) of the site of deposition. So, it will be needful to examine how the properties of the water overlying the site of deposition influence the regional distribution of organic matter in the sediments. It seems difficult to analyze the dynamical complexity throughout the year concerning oceanographic conditions in a given area. On the other hand, the mass properites of the sediments are influenced sensitively by the variation of the water column overlying the site of sedimentation. A study of such mass properties of the sediments will suggest the integrated contribution of oceanographic environment to subaquatic accumulation on the bottom floor.

In this paper, the regional distribution of marine humus in the sea to the southeast of Hokkaido is discussed being based upon the results of the serial observation on the oceanographic conditions (Kotō, 1952) or the mass properties of the bottom samples as determined by mechanical analysis. The submarine topography (Ōgaki *et al*, 1953) of the area under discussion appears to be rather monotonous. The slope of the shelf is gentle and there is not any large river supplying any good amount of terrigenous debris. The oceanographic conditions, consequently, will probably be the most important factor controlling the sedimentary accumulation on the bottom. So, the area seems to be suited for the purpose of investigating the influence of oceanographic environments upon organic accumulation in sediments.

The Hokkaido Regional Fisheries Research Laboratory undertook during 1948-1952 to investigate the bottom topography and sediments of the off-shore fishing grounds at about 100 - 1000 meters depth all around the coast of Hokkaido.

The bottom survey of the present area was made during the 3-21st of September,

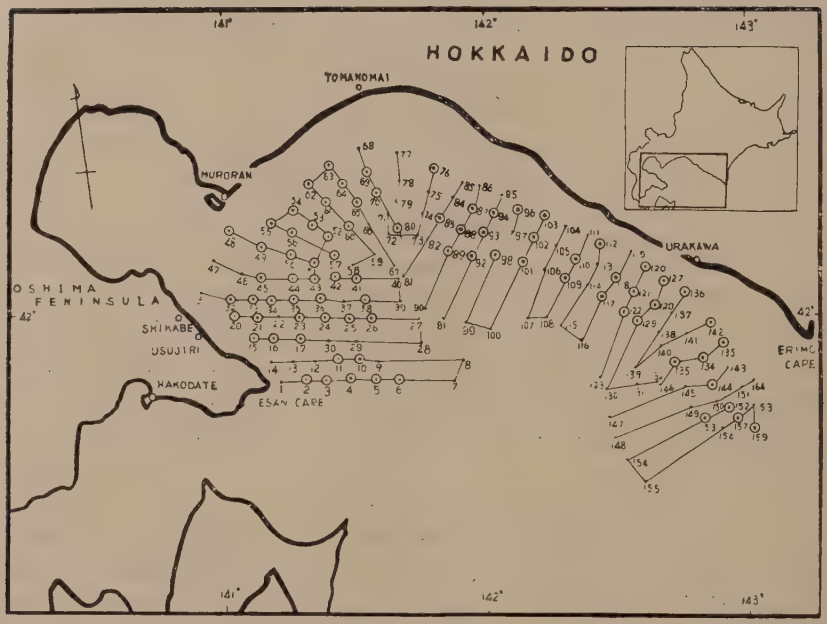

Fig 1. Stations of observation in the area to the southeast of Hokkaido (August 3 - 20, 1952)

1952, as one of the series of surveys by the Laboratory. The author undertook a chemical investigation dealing with the bottom sediments, of which bottom samples were obtained by Mr. H. Kosugi of the Laboratory and Mr. S. Tanaka, a student of the author's university, on shipboard TANKAI-MARU (68 tons), the research vessel of the Laboratory. The survey was conducted at intervals of four miles, so the bottom samples of 82 stations were observed after sampling, and 78 bottom samples from them were subjected to investigation at the laboratory of the university.

II. Methods employed

The oceanographic observation has been carried out with good position controls. For obtaining locations accurately, not only was the visible or sextant method employed, but other kinds of instrumental controls were used. Echo-sounding has played practically a very important role in performing the investigation of topography.

Bottom samples were obtained by using a small coring device or snapper. The samples obtained thus were submitted to laboratory investigation. At the same time, for preventing deterioration, the larger remains of benthos or weeds found in sediments were stored in vials containing formalin or spirit, and submitted later to biological

investigation.

Of the bottom sample dried at 100–105°C, the organic carbon content was determined by using Turin's (1931) modification of Schollenberger's (1927) method: The sample was oxidized by treating with an excess of potassium dichromate, after which the remained dichromate was determined by titration with ferrous ammonium sulphate. Although the method is not absolutely accurate, it is rapid and convinient, moreover duplicate analyses of the sediments checked to within one per cent.

The content of total nitrogen in the dried sample was determined by using the common Kjeldahl method.

For obtaining as accurate as possible knowledge of dynamical processes of sedimentation in the present area, the following laboratory method on mass properties was used for the bottom samples from the area :

From the mechanical analysis data a cumulative curve was drawn for each sample on logarithmic probability paper and the median diameter and the first and third quartile measures were obtained from the curve. From these measures, Trask's (1932) coefficients of sorting and skewness were computed. The sorting coefficient is determined as

$$S_o = \sqrt{\frac{Q_1}{Q_3}}$$

and the skewness coefficient as

$$Sk \doteq \frac{Q_1 Q_3}{Md^2}$$

where Q_1 and Q_3 ($Q_1 > Q_3$) are the quartile measures and Md is the geometric median diameter. Detailed description of the mechanical analysis is given as follows :

Each sample was air-dried, then crushed with rubber pestle, and ten grams of the crushed test sample was used for mechanical analysis. Test sample was soaked for two or three hours in hot water adding a few drops of ammonia, then wet-sieved through 0.06 mm mesh sieve to separate sand fraction from the silt. The settling method was used for analyzing the fraction finer than 0.06 mm in grain size. The clay fraction finer than 0.01 mm in grain size was separated from the silt fraction ranging from 0.01 mm to 0.06 mm in grain size. After a while, the sand fraction remaining in the sieve was analyzed by the common wet method of sieving.

Labratory work, next, led to microscopic observation of planktonic remains accumulated in the sediments, for ascertainment of how the organic remains had affected the accumulation of organic matter in the bottom floor.

III. General description of the area under discussion

There is at present little information available concerning the oceanographic character of this area. H. Kotō (1952), the author's colleague, has been investigating the oceanographic condition of the present area, since 1949, for clarifying the

hydrographical mechanism of the water exchange in Funka Bay located to the westward of that area. One may understand the oceanographic characteristics of the investigated area after reading his following interpretation regarding the oceanographic condition observed in the mouth of Funka Bay (May 1950, Fig. 3):

The Tsugaru Current, or a branch of the Tsushima Current, has branched off northwards after passing through the Strait of Tsugaru. As the branched current develops gradually, the upper water of the Oyashio Current which had been staying ever since winter has separated into the two parts in the northwestern part of the area as illustrated in Fig. 3. The water mass separated thus may stay usually at the separated state until the influence of the Oyashio Current will increase again in autumn, although both the salinity and the temparature of the separated water will become somewhat higher owing to being mixed gradually with the water of the warm current. The characteristic equilibrium mentioned above appears fairly stable until the influence of the warm current becomes weak in autumn. The Tsugaru Current begins to regress in November. At the same time, the influence of the Oyashio Current appears to be developing gradually; the cold water presses the warm water to southward and flows into Funka Bay in winter. Then, the water exchange does occur in the bay.

After all, the area under discussion might be divided into the following subareas from the oceanographic point of view: The open sea (1) appears to be usually under the influence of the Tsugaru Current. But the area adjacent to the Oshima Peninsula (2) will be complicated in the motion of the water owing to the complicated configuration of the part, while the area off the coast of Hidaka (3) is accustomed to be under the influence of the Oyashio Current, especially in autumn and winter. Furthermore, at the western part in the vicinity of the mouth of Funka Bay (4), a part of the upper water of the Oyashio Current has been isolated hydrographically by the developing strength of the Tsushima Current in spring and summer, and there is usually found a kind of counter current against the branched current of the Tsugaru.

In texture, the sediments in the area are mostly sandy mud and become muddy with increasing water depth of the site of deposition (Fig. 4). Remarked sedimentation of volcanic materials such volcanic ashes or pumices is observed at the mouth of Funka Bay and off the eastern coast of the Oshima Peninsula. Such materials would be brought from the volcanoes, i.e., from Komagatake (1142 m), Usudake (732 m) and Tarumaisan (1026 m). It is notable that there are found distribution of gravel off Urakawa but the gravel observed was not pumice. Sand with shell fragments are found on the bottom floor lying between Tomakomai and Mitsuishi. In the sediments enriched in sand or gravel, there was found a pretty large amount of benthic animals, either living or dead, viz., sea worms, brittle stars, heart urchins, amphipods or young shells of scallop.

IV. General view of marine humus distribution in the area

The amounts of organic materials in the sediments have been summarized in Table 1. The regional distribution of organic contents in sediments have been illustrated in Figs. 5-7. These figures might indicate some correlation between the humus distribution and the environmental conditions at the site of deposition.

The abundance of organic accumulation was indicated by the contents of organic carbon and total nitrogen, which might vary with water depth at the site of deposition. The relation between the organic content and the corresponding water depth was examined statistically, and the findings were summarized in Table 2. According to it, there was found a fairly positive correlation between the two variables but the ratio of carbon to nitrogen had almost no correlation to the water depth.

It is remarkable that organic accumulation in the sediments appears developing with increase in the water depth and that the humus distribution somewhat resembles the sedimentary map of planktonic remains (Fig. 8).

In the open sea below 700 meter depth, a pretty good amount of organic matter, 1.8-2.4% C or 0.18-0.23% N, may be accumulated in the sediment. On the other hand, in the nearshore or comparatively shallow bottom, organic accumulation will be not so remarkable as in the case of the deeper sites; especially, an accumulation under 0.1 per cent in nitrogen content is observed on the continental shelf or at the offing east of Cape Esan. Further it is very remarkable that a strange accumulation of marine humus is observed in the western part of the area, where a part of the water of the Oyashio is customarily isolated from the water of the Tsugaru as emphasized in the previous section. At the center of that part, a comparatively abundant accumulation of organic matter in sediment is observed in contrast with a poor accumulation at the bottom neighboring the above center. Such characteristic humus distribution may be due to some influence of a kind of up-welling that usually occurs in this part.

A strip of poor accumulation of organic carbon in sediment pushes out off the coast to the northwest of the present area; that strip may be caused by some sort of erosion as induced by the water of Tsugaru Current approaching the coast. For a while, not only the abundance but also the character of organic materials in the sediments appears farily complicated in the area to the northeast of Cape Esan; that will be due to the complexity of oceanographic conditions in this part.

The local variation of the ratio, C/N, seems to be very interesting in reference to either terrigenous supplies or oceanographic character in the area. A belt possessing a ratio comparatively large in value runs along the continental slope, as shown in Fig. 7, where the major water of Tsushima Current is used probably to contact with the other waters near the coast. The noticeable portion of the belt lying in the northern part of the present area appears to be contributed largely by remarkable decomposition of

nitrogenous substances in comparatively fresh terrigenous debris, judging from the remarkable reduction of nitrogen content. The organic detritus has perhaps been supplied from land by rivers on the coast and transported by the water of Tsugaru Current flowing to southeast. Another large ratios are also found at the central part of the northwestern area and off Usujiri on the Oshima Peninsula coast. At both of these areas, the existence of eddies has been suggested in the preceding section. It is very notable further that some singular stations having extremely small ratio are located nearby the area indicating an extremely large ratio.

After all, comparatively large ratios, 10 or over, will be found in the sediments of certain characteristic areas which will usually be found to be under the influence of current rip in broad sense. In such sediments, nitrogenous substances of fresh organic matter will be decomposed more actively by bacteria in comparison with non-nitrogenous substances because of supplying a fairly good amount of oxygen for the bacterial decomposition. Waksman (1938) has shown that fresh organic matter attacked by bacteria will first lose nitrogen than carbon until a more or less definite equilibrium ratio is attained.

Preliminary examination of organic remains shows that the abundance of skeletal residues of diatom accumulated in the sediment appears nearly analogous to that of the nitrogen content. Organic remains might consequently contribute effectively to sedimentary accumulation of nitrogenous substances in the bottom floor. It is also one of the characteriatics of the area under discussion that the fragments of sponge spicule were observed in almost all of the bottom samples from this area.

V. Sedimentological inspection on organic accumulation in sediments

The median diameter and Trask's coefficients of sorting and skewness of the sample were investigated to see if these sedimentological indexes after mechanical analysis of the sample would show any relationship not only to the various topographic or oceanographic environments but to the regional distribution of organic matter in sediments.

Figure 9 shows a bottom sediment map of the area under discussion, but that will not always be satisfactory for representing the dynamical process of sedimentation occuring therein. So, a contour map of median size based upon the cumulative distribution curve on grain size of sediment is shown in Fig. 9, which was made for the fraction of the bottom sample finer than two milimeters in grain size. The median map illustrates that a remarkable accumulation of grains finer than 0.025mm is observed in the northwestern part of that area although these finer sediments are usually found in the offing deeper than 500 meters. Moreover, off the coast between Urakawa and Cape Erimo, it is remarked, the sediments have the finest grains, 0.001 mm or less in median diameter. It appears that these characteristic regions as emphasized above are located

in the areas where there may usually occur some eddy current by contact of different masses of water.

Viewing the relationship of sedimentological indexes, as Md, S_o and Sk, of the bottom sample to the water depth at the site of deposition, one can scarcely find any distinguished correlation between them as a whole.

The bottom samples from the investigated area were classified into several groups, as shown in Fig. 10 and Table 3, on the basis of the shape of cumulative curve on grain size of sample. The area under discussion is divided as illustrated in Fig. 11 into several regions with reference to sediment type as well as to oceanographic environments. Such partition of the area will be useful in examining the correlation between organic accumulation in sediment and dynamical process of sedimentation taking place in the site of deposition. Examination of the sedimentary process appears very useful for investigating the oceanographic environment. These regions divided thus may be described as follows:

1) A – Region :

This region is the relatively pelagic part of the investigated area, in which water depths range from 500 meters to 840 meters, thus appearing to be under the influence of the Tsugaru Current. The region possesses sediments with fairly fine median diameter's, 0.010–0.045 mm, being so poor-sorted as to indicate 12.3 in S_o averaged. These sedimentological characters indicate that the sedimentation occurring in this region appears remarkable rather in deposition process than in erosion or transportation ones. Relatively poor sorting in A_2– region seems to indicate the conceivable presence of a kind of current rip which usually results from contact between the water of the Tsugaru and the coastal water.

In short, an inspection of the sedimentological characters shows that A–region should be characterized as pelagic or hemipelagic.

Sedimentary accumulation of organic matter seems relatively abundant, that is to say, the average content of organic carbon in the sediments ranges from 1.21% to 1.66% and that of total nitrogen from 0.143% to 0.182%. Decomposition of organic matter in sediment appears fairly active and the ratio of carbon to nitrogen is given as the average ratio near 8.6. The sediments which have been comparatively poorly sorted in A_2–region appear to be rather less abundant in organic matter (ignition loss) than those of the other parts, as A_1 or A_3.

2) B – Region :

The major part of this region is the shelf adjacent to the Oshima Peninsula; the movement of water is complicated owing to the geographical configuration. The sedimentological characters in this region indicated that the median diameter of sediment

is of coarse or medium-sand and well-sorted as indicated usually by 2 - 3 in S_o. Especially, the sediments in B_1-region are better sorted. The sediments in the B region, however, seem somewhat poorly sorted in the fine fraction. This tendency is more remarked in B_1- or B_3- region. It is otherwise very noticeable that the sediments in the vicinity (B_4-region) of Station 16 are extremely poorly sorted, 32.7 in S_o, especially of their fine fractions, and 0.03 in Sk. These coefficients regarding B_4-region will indicate that there will usually be found a characteristic deposition of sedimentary particles in this region. This noticeable deposition may be due to a small eddy which is usually found near the coast and influenced by configuration of the coast.

In the B-region, organic accumulation in the bottom appears not so remarkable as that in A-region, that is, the sediments have organic carbon contents ranging approximately from 0.3% to 0.8%, or nitrogen contents from 0.04% to 0.12%. Comparatively small values, 5 - 7, in the ratio C/N are found to predominate in this region, although somewhat divergent values are observed in B_1-region. These facts show that there will be found not only poor accumulation of terrigenous organic matter owing to better sorting but also to complicated condition of oceanographic environment.

3) C - Region:

The continental shelf off the coast (Hidaka) west of Cape Erimo belongs to this region. This region may be divided into two parts which are characterized on the basis of sediment type of bottom samples as well as their oceanographic environment. One of these two parts is the area consisting of C_1 and C_2, lying intermediate between Urakawa and Cape Erimo. The sediments of the above area are mostly clay or silt; their poor assortment is remarkable, the median diameters are finer than 0.01 mm and sorting coefficient 9 or over. These sedimentological characters in C_1-region show that there must occur a characteristic sedimentation in which the deposition process will be rather more important than the other process such as erosion or transportation in this region; then there is the possibility of the occurrence of a kind of eddy or a counter current. Such an eddy current will be induced from the contact of the two currents of the Tsugaru and the Oyashio, of which the latter flows bypassing Cape Erimo. It is moreover noticeable that the sediment type in the C_1-region is nearly analogous to that in A_1-region or D-region. Organic accumulation, however, in C-region is not as abundant as that in the analogous region in sediment type mentioned above. Also the qualities of organic materials accumulated in the sediments of the C_1-region appear rather terrigenous judging from the high ratio of carbon to nitrogen.

The other part suggested above occupies most of the C-region comprising C_3, C_4, C_5 and C_6. The flows of both the Tsugaru Current (in spring and summer) and the Oyashio Current (in autumn and winter) seems to be fairly influenced by the change of

the corresponding season. The sediments, consequently, are well sorted as indicating the S_o ranging 1.4 – 4.6 or mostly near 2, but the finer fraction appears rather less sorted than the coarser ones. The sediments in C_3-region, moreover, have median diameter near 0.05 mm and appear rather less sorted, 0.31 – 0.37 in Sk, than those in the other parts of the C region do. These sedimentological features of the C_3-region may look similar to thsoe in A_3-region; there will usually be suggested the existence of a current rip in this region and a fairly good amount of organic matter is accumulated in the bottom sediments.

In C_4-region occupying the major portion of the C-region, the sediments have 0.06–0.15 mm median diameter, being well sorted and indicating somewhat symmetrical size distribution, where the best sorted sediments have median diameter near 0.13 mm.

As the sediments in the regions of C_{3-6} have been well sorted by flows of currents, the organic materials in these regions will be comparatively lacking in the sedimentary accumulation but rather terrigenous in character. Such terrigenous characters of organic materials in the sediments will indicate some contribution of organic debris supplied by rivers on the coast to the north of the investigated area.

4) D – Region :

D region is the northern part of the area under discussion. It is complicated in oceanographic environments as emphasized in the previous section; then the sediment type of the bottom samples should be very changeful.

The sorting of sediments in this region appears not only extremely poor but also widely variable. Moreover the cumulative curve on grain size of the bottom sample appears somewhat singular in shape which finding may suggest some influence of mass movement of unconsolidated sediments in the form of mud flows. The transportation effect suggested above appears to be more remarked in the respective stations, marked E in Fig. 10, of 42,65 and 76 judging from the abnormal shapes of grain-size cumulative curves obtained from samples of the three stations. A characteristic sedimentation is clearly found at the central part, D_1, of the D-region; the sediment type of the sample from D_1-region indicates median diameter near 0.015 mm and sorting coefficient near 7. This seems somewhat analogous to the type of such a pelagic region as A_1, although the size-distribution of the sample from D_1-region is skewed towards the coarser size. These feature of D_1-region may be somewhat peculiar in effects from eddy or rip current. Both inspections on the regional distribution of granule (Fig. 4) and on the skewness towards the coarser size found in grain-size distribution curve may indicate that a coast line in geological age would be found in the vicinity of the D_1-region. The above geographical suggestion regarding the characteristic mass properties of the bottom sample, however, will need more investigations in future. A fairly abundant

accumulation of organic matter, 0.14 – 0.21%N is observed in D_1-region, while D_0-region neighboring the D_1 has some strange stations, as 49 or 52, which indicate fairly high ratio of carbon to nitrogen near 12.5. This fact will suggest not only complexity in water diffusion towards vertical or holizontal direction but transportation of unconsolidated sediments.

Sedimentological inspection of the ratio C/N shows that rather higher ratio may be observed in the sediment which has been relatively poorly sorted and which shows a strange curve of grain-size distribution with connection to transportation process over the bottom floor.

VI. Relationship between sedimentological indexes and accumulation of organic matter in sediment

The sedimentological indexes, as median diameter or coefficients of sorting and skewness, of the bottom sample were examined to see whether they would indicate a relationship to the character or abundance of organic materials accumulated in the sediment. These relations are illustrated in a series of Figures 13 – 15.

Although organic accumulation appears rather correlative to median diameter (Fig. 13), it will be hard in general to see any definite correlationship to the coefficients of sorting and of skewness. Further inspection in detail leads to an approximate estimation on a relationship between the organic accumulation and these indexes.

It appears that the finer the sediment is in diameter the more abundant in organic accumulation. As to the sediment finer than 0.01 mm in median diameter, however, there will be found something of a tendency for a reduction in organic content to accompay a reduction in diameter of grain size.

Plots of the organic content against the sorting for the relatively well sorted sediments, as indicating S_o below 5, fall in some reasonable mass. While the plots on the poorly sorted sediments seems almost to be dispersed. With the progress of the sorting, the well sorted sediments appear to be reduced in organic contents, particularly more remarkably in nitrogen content. In the others, the plots regarding the poorly sorted sediments will scarcely show as a whole any definite relationship to the degree of sorting because of their random deviations, but further detailed examination may suggest some relation between sorting degree and organic accumulation of the poorly sorted sediment. The quantity of organic carbon in sediment will decrease with reduction in the degree of sorting; otherwise, that of nitrogen will show some increase with reduction of sorting, until a more or less definite ratio of carbon to nitrogen will be attained. Further it is noticeable that the constancy of the carbon nitrogen ratio appears rather more reliable in the well sorted sediments than in the poorly sorted ones. This fact will show that the better sorting leads to settling of fresh terrigenous debris comparatively large in shape

as well as to the removal of colloidal detritus of organic matter which has been humi-nized progressively. The progress of sorting appears moreover to render the material more profitable for the inhabitation of benthic animals because of the presence of a pretty good supply of oxygen or foods.

Plots of organic content against the skewness on the well sorted sediments in B-region show that the considerable deviation of skewness appears not to exert much influence in controlling organic accumulation in the bottom. This fact will suggest that the abundance of organic matter accumulated in the well sorted sediments will be more largely contributed by large organic debris or remains than fine detrital materials. The most sediments of C region, as C_3, C_4, C_5 and C_6, have rather coarser median diameter in comparison with those of B region, but the sediments of the C have been sorted similarly to those of the B-region. Now, it appears that the abundance of organic matter decrease with approach of the skewness to unity.

Plots on the poorly sorted sediments such as those of A_1- or D-region are dispersed on the diagram; it is scarcely possible to see any relationship between the organic content and the skewness coefficient of sediment. These examinations show that the organic accumulation in poorly sorted sediments were probably contributed by detrital organic matter.

VII. Conclusion

Regional distribution of marine humus (organic matter in sediment) in the sea to the southeast of Hokkaido was investigated with reference to the oceanographic environment of the site of deposition. As the oceanographic character of the site of deposition will contribute to the mass properties of the bottom sediment, sedimentological examination of the mass properties was attempted as described in the present paper for discussing the relation of organic accumulation in bottom to the oceanographic environment.

Statistical examinations on the relation of the organic accumulation to such a topographic factor as water depth at the site of deposition indicated that there is a fairly positive correlationship between the organic content and the water depth, but that the ratio of carbon to nitrogen showed scarcely any correlation to the water depth.

It is true that sedimentary accumulation of organic matter will be susceptible to the influence of oceanographic surroundings, but the local variation of the carbon nitrogen ratio of the sediment seems very interesting in relation to either terrigenous supply or oceanographic condition in a given area. It was remarked in the area under discussion that a comparatively large ratio above 10 was almost always observed in the sediment which was customarily under the influence of rip current in broad sense.

The abundance of organic remains, particularly of skeletal residues of diatom, in the sediment appeared nearly analogous to that of the nitrogen content. Consequently

organic remains might fairly influence the sedimentary accumulation of nitrogenous substances on the bottom floor.

Sedimentological indexes, e. g., median diameter and Trask's coefficients of sorting and skewness, of the bottom samples were investigated, after mechanical analysis, for discussing the relation of them to the regional distribution of marine humus as well as to the influences of topographic or oceanographic environments.

Here, the samples were classified into several types of sedimentation on the basis of the shape of cumulative frequency curve on grain size. Further, the area under discussion was divided into several regions with reference to the sediment type of the bottom samples as well as to the oceanographic characters. Such partition of the area would be reasonable for clarifying any correlation between the organic accumulation and dynamical process of sedimentation going on at the site. Examination of the sedimentary process appeared of much use for investigating the oceanographic environments in the area.

Although organic accumulation in bottom appeared rather correlative to median diameter, it would be hard in general to observe any definite correlation to the Trask's coefficients. The abundance of organic matter in poorly sorted sediment seemed to be rather more variable according to its location. Otherwise, the well sorted sediment seemed to be decreasing in respect to organic content with the progress in the sorting; that would be even more remarkable in the case of their nitrogen contents.

In the poorly sorted sediments, the amount of organic carbon decreased while that of nitrogen rather increased with reduction in the degree of sorting process, until a more or less definite ratio of carbon to nitrogen tended to be attained.

Of the well sorted sediments, a considerable deviation of skewness appeared not to have much influence upon organic accumulation in bottom. The abundance of organic matter, however, decreased with approach of the skewness to unity. Of the poorly sorted sediments, it is scarcely possible to observe any relation between the organic content and the skewness.

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References

1) Kato, K. (1951). Chemical studies on marine deposits. Part 3. On the distribution of marine humus contents in the sea to the northwest of Hokkaido Island. *Bull. Fac. Fish., Hokkaido Univ.* 2(1),

10–30. (in Japanese appended English abstract).

2) Kotō, H. (1952). Oceanographic observation of Funka-Wan. *Funkawan-Gyogyō-Keiei-Antei-Kisochosa* (Interim Reports). No. 2, 1–17. (in Japanese).

3) Ōgaki, K., Kosugi, H. & Tomabechi, Y. (1953). Submarine topography and distribution of bottom sediment on deep sea fishing ground of Hokkaido. *Bull. Hokkaido Reg. Fish. Lab.* (9), 1–16. (in Japanese appended English abstract).

4) Schollenberger, C. J. (1927). A rapid approximate method for determining soil organic matter. *Soil Sci.* **24**, 63–68.

5) Tiurin, I. V. (1931). A new modification of the volumetric method of determining soil organic matter by means of chromic acid. *Pedology* **26**, 36–47.

6) Trask, P. D. (1932). *Origin and environment of source sediments of petroleum.* A. P. I., 323 p. Gulf Publ. Co.

7) Waksman, S. A. (1938). On the oxidation of organic matter in marine sediments by bacteria. *Jour. Mar. Res.* **1**, 101–118.

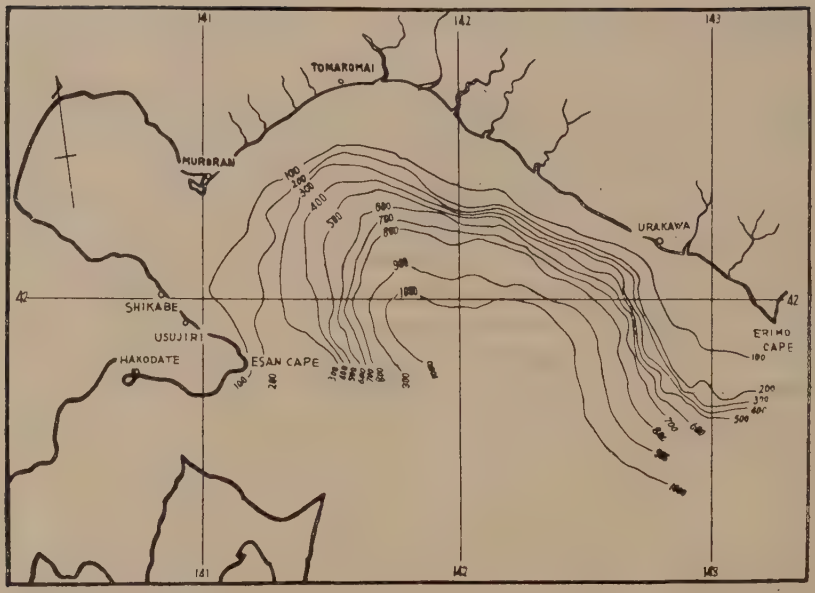


Fig. 2. Submarine topography of the area to the southeast of Hokkaido

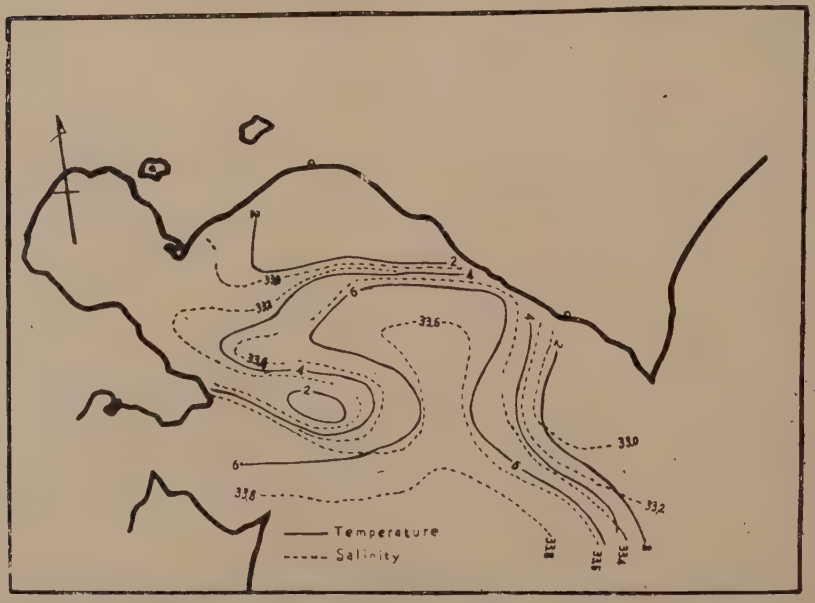


Fig. 3. Oceanographical view of the area to the Southeast of Hokkaido (50 meters layer, observed by H. Kotō; May 1950)

Fig. 4. Bottom character in the area to the southeast of Hokkaido

Fig. 5. Distribution of organic carbon content in sediments
(The area to the southeast of Hokkaido)

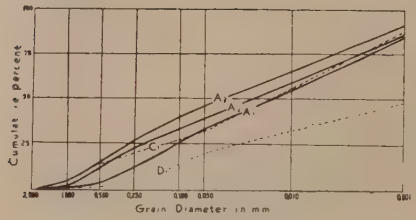
Fig. 6. Distribution of total nitrogen content in sediments
(The area to the southeast of Hokkaido)

Fig. 7. Distribution of the ratio, C/N, in sediments
(The area to the southeast of Hokkaido)

Fig. 8. Distribution of diatom residues accumulated on bottom floor (The area to the southeast of Hokkaido)

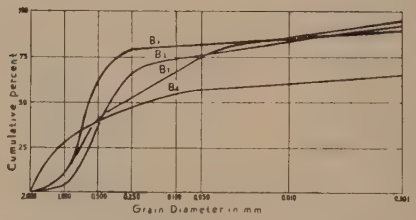
Fig. 9. Median map in the area to the southeast of Hokkaido (mm)

A – Region :



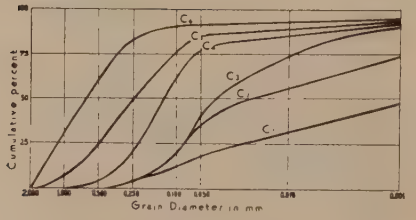
A_1 : H89, A_2 : H41,
A_3 : H80; C_1 : H159, D_1 : H61

B – Region :



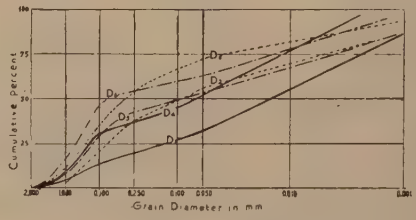
B_1 : H4, B_2 : H10, B_3 : H35,
B_4 : H16

C – Region :



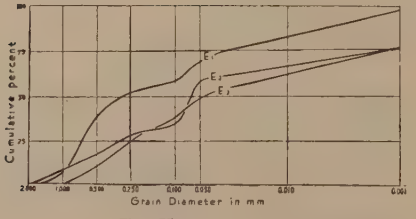
C_1 : H159, C_2 : H129, C_3 : H118,
C_4 : H144, C_5 :H94, C_6 : H157

D – Region :



D_1 : H64, D_2 : H69, D_3 : H62,
D_4 : H48, D_5 : H51, D_6 : H50

E – Region :



E_1 : H65, E_2 : H76, E_3 : H42

Fig. 10. Graphs of cumulative curves showing sediment types

Fig. 11. Regions divided owing to sedimentological characters (The area to the southeast of Hokkaido)

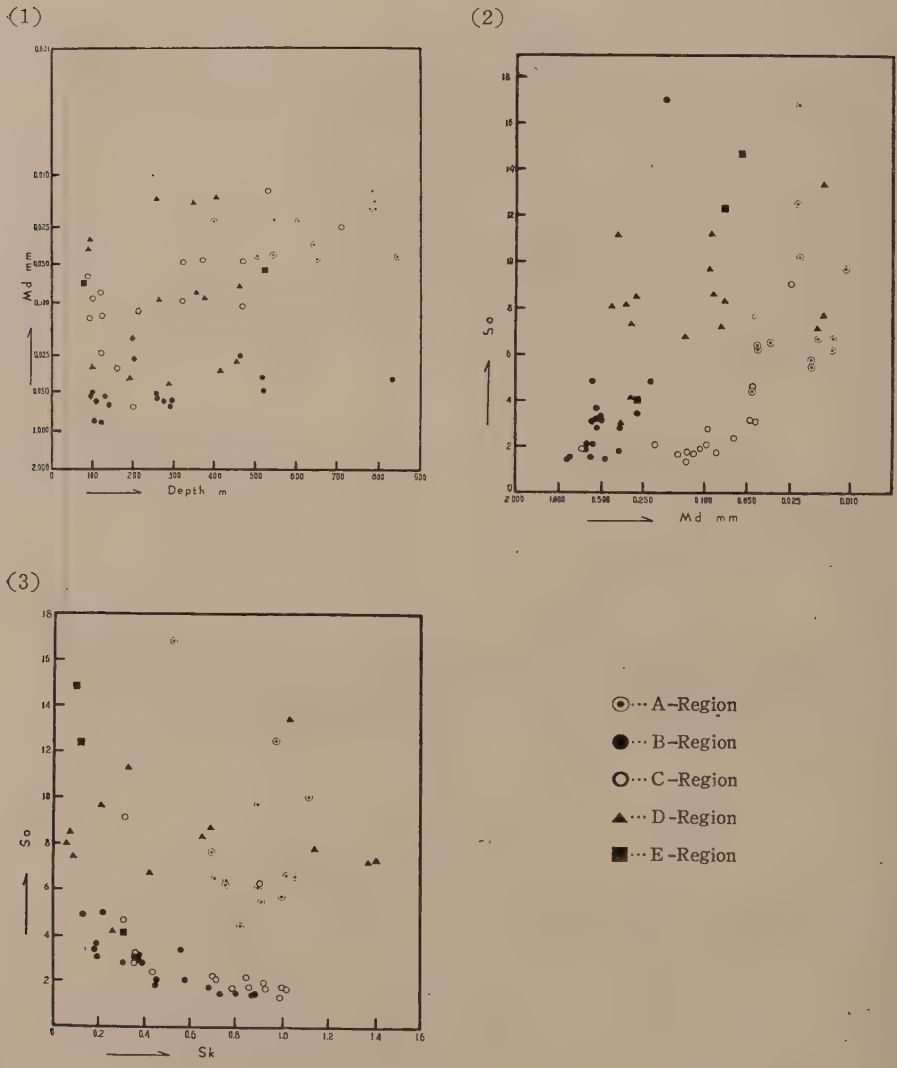


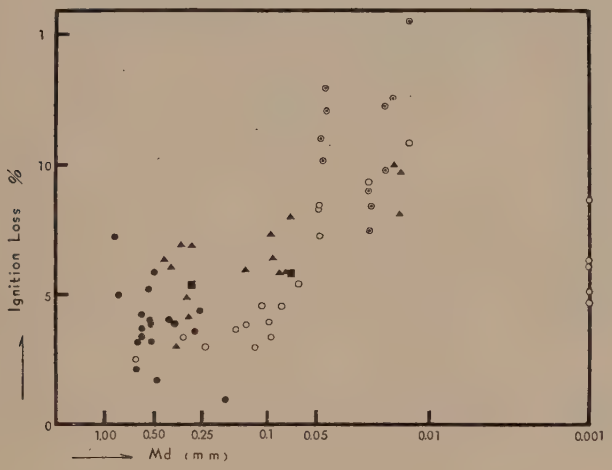
Fig. 12. Relation of the geographic region to sediment type

(1) Median diameter plotted against water depth

(2) Sorting coefficient plotted against median diameter

(3) Sorting coefficient plotted against skewness coefficient

(1)



(2)

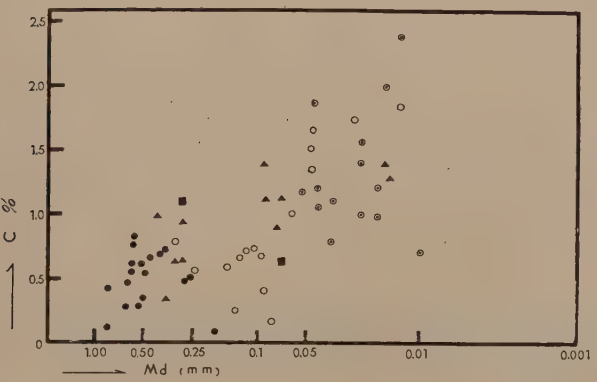


Fig. 13. Relation of median diameter to organic content in sediment

(1) Ignition loss plotted against median diameter

(2) Organic carbon content plotted against median diameter

⊙··· A-Region ●··· B-Region ○··· C-Region ▲··· D-Region ■··· E-Region

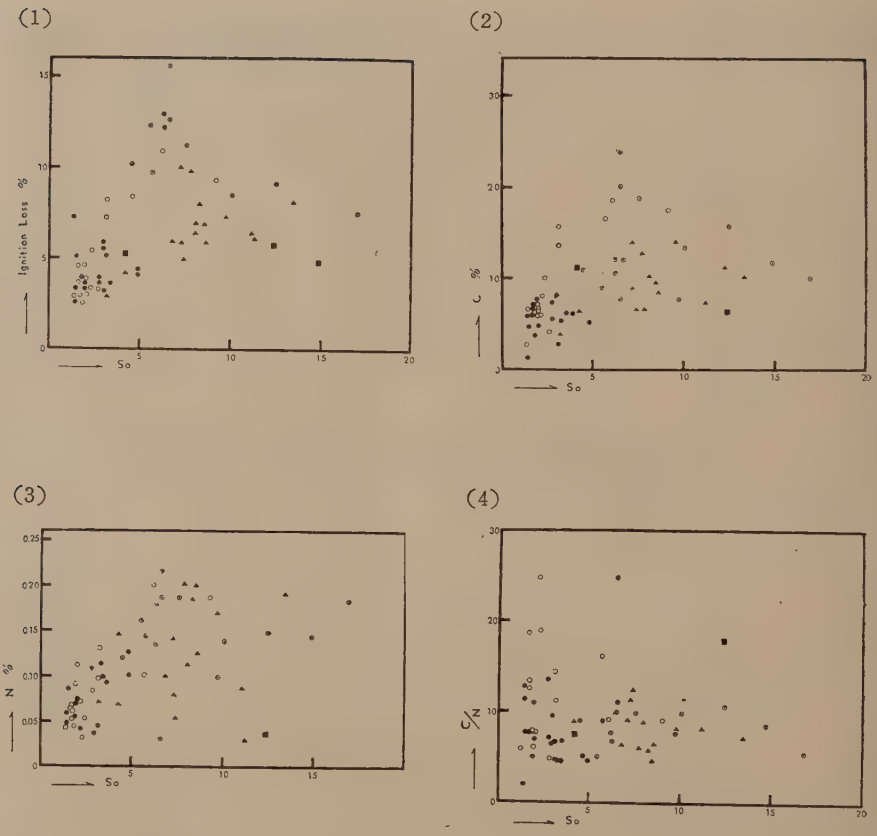


Fig. 14. Relation of sorting coefficient to organic content in sediment

(1) Ignition loss plotted against sorting coefficient
(2) Organic carbon content plotted against sorting coefficient
(3) Total nitrogen content plotted against sorting coefficient
(4) The ratio, C/N, plotted against sorting coefficient

⊙··· A-Region ●··· B-Region ○··· C-Region ▲··· D-Region ■··· E-Region

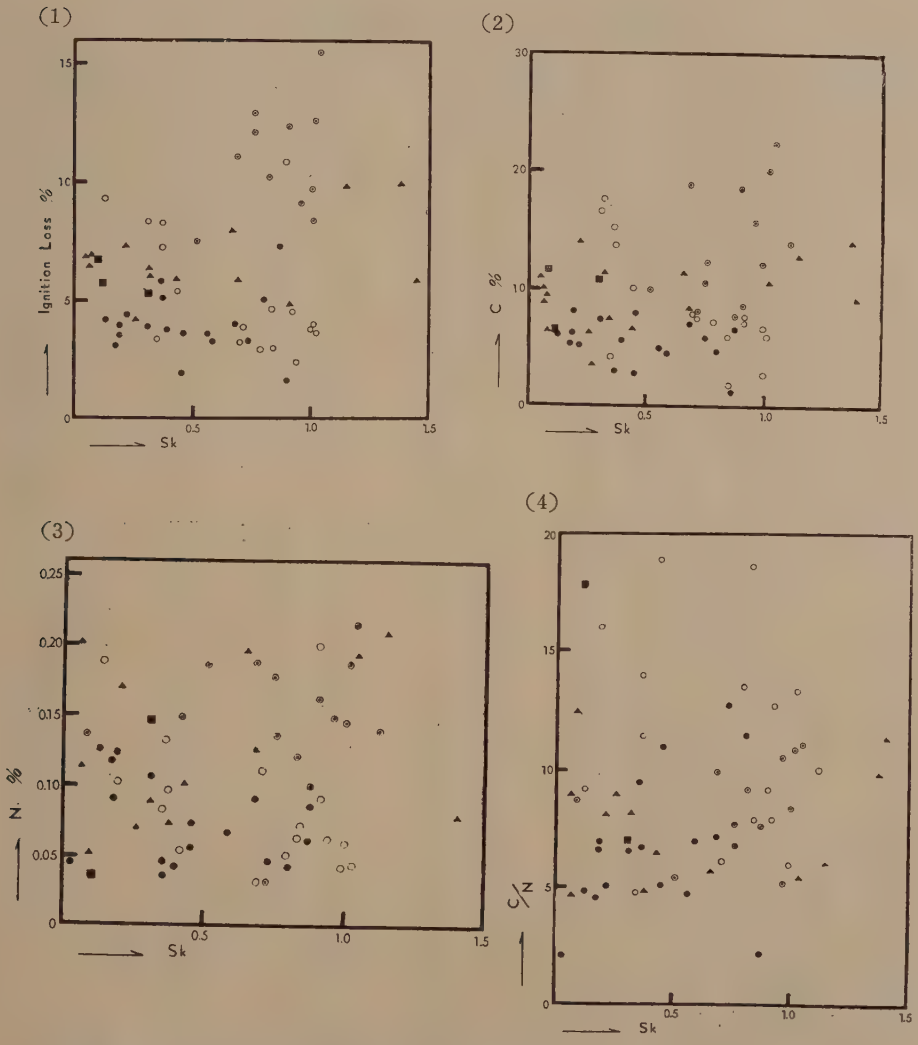


Fig. 15. Relation of skewness coefficient to organic content in sediment

(1) Ignition loss plotted against skewness coefficient
(2) Organic carbon content plotted against skewness coefficient
(3) Total nitrogen content plotted against skewness coefficient
(4) The ratio, C/N, plotted against skewness coefficient

⊙··· A-Region ●··· B-Region ○··· C-Region ▲··· D-Region ■··· E-Region

Table 1. General properties of bottom samples from the area to the southeast of Hokkaido (3–20, September, 1949)

St. No.	Date (Sept. 1949)	Location Lat. N	Location Long. E	Water depth (m)	Texture of sediment	Organic carbon (%)	Total nitrogen (%)	C/N	Ignition loss (%)	Diatom residues	Silicious sponge
H 2	3	41°48′7	141°18′7	249	SM	0.18	0.066	2.73	0.48	R R	C
H 3	3	41°48′5	141°23′6	299	SM	0.53	0.044	12.05	1.38	R	A
H 4	3	41°48′5	141°29′3	274	SM	0.58	0.046	12.83	3.37	R R	C
H 5	3	41°48′7	141°34′8	521	G S M	0.66	0.085	7.77	1.69	C	C
H 6	3	41°48′7	141°40′0	830	G S M	0.70	0.097	7.22	4.05	R	C
H 10	3	41°52′2	141°31′1	527	S M	0.74	0.107	6.92	3.92	C	C
H 11	3	41°51′8	141°26′0	297	S M	0.79	0.072	10.97	3.67	C	C
H 15	4	41°55′8	141° 7′0	102	G M	0.47	0.041	11.46	5.07	C	
H 16	4	41°55′8	141°11′7	198	G S M	0.09	0.043	2.09	0.85	R R	
H 17	4	41°55′5	141°18′3	288	G M	0.82	0.122	6.72	3.59	C	
H 20	8	41°59′5	141° 2′5	97	G S M	0.34	0.036	9.45	5.88	R	
H 21	8	41°59′5	141° 7′8	123	G S M	0.13	0.060	2.17	7.32	C	C
H 23	8	41°59′4	141°18′3	290	S M	0.28	0.055	5.09	1.99	C	C
H 24	8	41°59′5	141°23′8	255	S M	0.55	0.118	4.66	3.23	A	A
H 25	8	41°59′0	141°29′7	459	S M	0.52	0.102	5.10	4.43	A	C
H 26	8	41°59′0	141°34′2	797	M	1.24	0.120	10.33	.....	C	C
H 32	9	42° 2′9	141° 1′6	98	G S M	0.30	0.045	6.67	5.16	C	
H 33	9	42° 2′8	141° 6′7	116	G S M	0.62	0.126	4.92	4.23		C
H 34	9	42° 2′5	141°11′5	133	G S M	0.56	0.041	13.66	3.80	C	C
H 35	9	42° 2′7	141°17′0	252	G S M	0.49	0.101	4.85	3.65	A	
H 36	9	42° 2′8	141°22′4	352	S M	0.84	0.126	6.67	5.89	A	C
H 38	9	42° 6′5	141°33′0	604	M	1.57	0.148	10.61	9.07	A	C
H 41	9	42° 6′6	141°31′0	541	M	1.39	0.140	9.93	8.45	C	C
H 42	9	42° 6′6	141°26′0	420	M	1.18	0.136	8.68	6.82	C	C
H 43	9	42° 6′4	141°21′5	355	M	1.21	0.176	6.88	8.94	A	C
H 44	9	42° 6′0	141°16′4	256	S M	0.62	0.091	6.81	4.04	R	
H 45	9	42° 6′0	141° 9′3	121	S M	0.46	0.057	8.07	.....	R	C
H 48	10	42°14′4	141° 1′2	75	G M	0.90	0.079	11.39	5.77	C	C
H 49	10	42°11′9	141° 8′9	98	S M	0.65	0.052	12.50	4.82	C	
H 50	10	42°10′2	141°15′2	193	S M	0.72	0.088	8.18	0.62	C	
H 51	10	42° 8′7	141°20′8	376	M	1.13	0.131	8.63	6.31	C	C
H 52	10	42°14′0	141°25′0	430	M	1.11	0.087	12.76	6.91	C	C
H 53	10	42°15′4	141°20′4	289	G S M	1.02	0.113	9.03	6.38	C	
H 54	10	42°18′1	141°16′5	139	G S(M)	0.47	0.067	7.02	3.26	R	
H 55	10	42°15′7	141°11′8	100	S M	0.66	0.101	6.54	5.93	C	
H 56	10	42°13′2	141°15′6	258	M	1.04	0.192	5.42	8.11	C	C
H 57	10	42°10′5	141°25′5	460	M	1.13	0.195	5.80	8.04	A	C
H 60	10	42°15′0	141°29′0	453	M	0.95	0.202	4.70	6.92	A	C
H 61	10	42°18′7	141°23′8	402	M G	1.28	0.209	6.12	9.83	C	
H 62	10	42°22′2	141°20′0	93	G S M	0.63	0.070	9.00	4.22	C	C
H 63	10	42°25′2	141°24′5	88	G S M	0.36	0.074	4.87	3.01	R	
H 64	10	42°22′0	141°27′6	348	M	1.40	0.142	9.86	9.96	A A	C
H 65	10	42°19′1	141°29′5	449	M S	1.11	0.146	7.60	5.32	A	C
H 69	13	42°24′5	141°33′5	285	M	1.39	0.170	8.18	7.34	A	C
H 70	13	42°20′8	141°34′4	399	M	1.01	0.183	5.52	7.52	A	C

(Table 1 continued)

St. No.	Date (Sept. 1949)	Location Lat. N	Location Long. E	Water depth (m)	Texture of sediment	Organic carbon (%)	Total nitrogen (%)	C/N	Ignition loss (%)	Diatom residues	Silicious sponge
H 76	13	42°25′0	141°48′1	79	S M	0.64	0.036	17.78	5.77	R	
H 80	14	42°14′6	141°41′4	648	M	1.87	0.187	10.00	11.18	A	C
H 83	14	42°16′1	141°49′4	530	M	1.85	0.201	9.20	10.91	A	A
H 87	15	42°18′4	141°57′2	160	S M	0.79	0.032	24.69	3.30	R R	
H 88	15	42°14′8	141°54′5	630	M	1.71	0.184	9.29	.....	C	C
H 89	15	42°11′2	141°51′6	785	M	2.01	0.186	10.81	12.63	C	
H 92	15	42°10′2	141°58′7	785	M	0.85	0.162	5.25	12.13	A A	C
H 93	15	42°14′3	142° 0′2	565	M	0.74	0.136	5.44	4.67	R	A
H 94	15	42°17′4	142° 2′1	120	G S	0.56	0.071	7.89	3.05	R R	C
H 96	16	42°17′7	142° 9′0	95	S M	0.59	0.044	13.41	3.67	R R	C
H 98	16	42°10′3	142° 4′0	820	M	.....	0.208	.....	.....	C	C
H101	16	42° 9′5	142° 9′2	840	M	1.21	0.178	6.80	12.14	C	A
H102	16	42°13′3	142°11′7	500	M	1.11	0.121	9.17	10.23	R	C
H109	16	42° 6′4	142°18′8	715	M	1.70	0.101	16.83	10.91	A A	C
H110	16	42° 9′5	142°21′0	465	M	1.66	0.103	16.12	8.42	C	C
H112	17	42°12′2	142°28′0	85	S M	0.26	0.043	6.05	3.87	R R	C
H117	17	42° 2′6	142°28′1	780	M	1.21	0.143	8.46	9.74	A	C
H118	17	42° 6′4	142°30′0	370	M	1.52	0.132	11.52	8.26	C	C
H120	17	42° 8′5	142°37′2	100	Sh S M	0.41	0.084	4.88	3.43	R R	C
H121	17	42° 4′0	142°33′7	540	M	1.05	0.136	7.72	12.92	A	A
H122	17	42° 0′8	142°31′7	780	M	2.39	0.215	11.12	15.56	A	C
H125	18	42° 6′0	142°41′1	245	M	0.77	0.100	7.70	3.73	R	A
H127	18	42° 6′0	142°41′1	95	S	0.70	0.065	10.77	4.24	R R	
H128	18	42° 1′9	142°38′9	320	M *s*	1.36	0.097	14.02	7.30	C	C
H129	18	41°58′7	142°35′7	705	M	1.74	0.188	9.26	9.32	C	C
H133	18	41°51′0	142°43′6	320	G S M	0.68	0.112	6.07	3.94	A	C
H134	18	41°52′0	142°49′7	115	S M	0.18	0.063	18.73	4.59	R	C
H135	18	41°55′1	142°54′2	90	S	0.81	0.048	16.88	6.23	C	C
H136	19	42° 3′8	142°46′4	85	G S	0.53	0.042	12.62	4.86	R	C
H142	19	41°58′6	142°51′7	90	S	1.00	0.053	18.87	5.43	C	C
H144	19	41°48′0	142°52′4	125	S M	0.67	0.060	11.17	4.08	C	C
H152	20	41°44′5	142°55′2	210	S M	0.72	0.053	13.59	2.97	C	C
H153	20	41°42′5	142°50′4	465	S M	0.73	0.092	7.94	4.60	A	C
H157	20	41°42′2	142°57′9	200	G S	0.76	0.062	12.67	2.52		
H159	20	41°41′5	143° 1′4	426	M	1.03	0.123	8.37	8.78	R	C

Table 2. Organic contents of the sediments and their relation to the water depth of the site of deposition (Sea, southeast of Hokkaido, Sept. 3-20, 1952)

	Number of individuals	Population mean (a=0.05)	Standard deviation (s)	Correl. coeff. (r)	Test of null hypothesis	Equation of regression
Organic-C	79	0.823 —1.057	0.500	0.689	S ≠ 0	C = 0.00149 d + 0.339
Total-N	80	0.0911—0.1175	0.0578	0.552	S ≠ 0	N = 0.000162 d + 0.0490
C/N	77	7.18 —8.86	3.70	−0.092	S ≠ 0	....

C : Carbon content(%) N : Nitrogen content(%) d : Water depth of the site of deposition (m)

Table 3. Relations of organic accumulation to mass properties of bottom sample

Table 3-1. A - Region

	St. No.	Depth (m)	Md (mm)	Sk	S_o	Ignition loss(%)	C(%)	N(%)	C/N
A_1	H 83	530	0.013	0.899	6.164	10.91	1.85	0.201	9.20
	H 89	785	0.016	1.019	6.633	12.63	2.01	0.187	10.81
	H 92	785	0.018	0.906	5.506	12.31	0.85	0.162	5.25
	H117	780	0.018	1.000	5.679	9.74	1.21	0.145	8.46
	H122	780	0.013	1.041	6.633	15.56	2.39	0.215	11.12
A_2	H 38	604	0.023	0.962	12.47	9.07	1.57	0.148	10.61
	H 41	541	0.022	1.113	10.10	8.45	1.39	0.140	9.93
	H 70	399	0.023	0.516	16.88	7.52	1.01	0.183	5.52
	H125	245	0.010	0.879	9.747	5.73	0.77	0.100	7.70
A_3	H 80	648	0.045	0.691	7.616	11.18	1.87	0.187	10.11
	H 88	630	0.035	0.713	6.566	.....	1.71	0.184	9.29
	H101	840	0.042	0.756	6.297	12.14	1.21	0.178	6.80
	H102	500	0.043	0.823	4.484	10.23	1.11	0.128	9.17
	H121	540	0.042	0.756	6.290	12.92	1.05	0.136	7.72

Table 3-2. B - Region

	St. No.	Depth (m)	Md (mm)	Sk	S_o	Ignition loss(%)	C(%)	N(%)	C/N
B_1	H 4	274	0.593	0.734	1.539	3.38	0.58	0.046	12.83
	H 5	521	0.480	0.880	1.490	1.69	0.66	0.085	7.77
	H 6	830	0.398	0.680	1.774	4.05	0.70	0.097	7.22
	H 11	297	0.578	0.456	2.038	3.66	0.79	0.072	10.97
	H 15	102	0.843	0.799	1.513	5.07	0.47	0.041	11.46
	H 21	123	0.878	0.865	1.408	7.32	0.13	0.060	2.17
	H 23	290	0.650	0.452	1.883	1.99	0.28	0.055	5.09
	H 34	133	0.542	0.395	2.817	3.80	0.56	0.041	13.66
	H 54	139	0.637	0.587	2.017	3.26	0.47	0.067	7.02
B_2	H 10	527	0.380	0.311	2.828	3.91	0.74	0.107	6.62
	H 17	288	0.582	0.195	3.025	3.59	0.82	0.122	6.72
	H 24	255	0.518	0.179	3.317	3.23	0.55	0.118	4.66
	H 25	459	0.264	0.220	4.858	4.43	0.52	0.102	5.10
	H 33	116	0.590	0.131	4.861	4.23	0.62	0.126	4.92
	H 44	256	0.540	0.193	3.614	4.04	0.62	0.091	6.81
B_3	H 20	97	0.508	0.364	3.066	5.88	0.34	0.036	9.45
	H 32	98	0.535	0.374	3.204	5.16	0.30	0.045	6.67
	H 35	252	0.280	0.560	3.435	3.65	0.49	0.101	4.85
B_4	H 16	198	0.186	0.032	32.71	0.85	0.09	0.043	2.09

Table 3-3. C-Region

	St. No.	Depth (m)	Md (mm)	Sk	S_o	Ignition loss(%)	C(%)	N(%)	C/N
C_1	H135	90	0.001	.....	.....	6.22	0.81	0.048	16.88
	H136	90	0.001	.....	.....	4.86	0.53	0.042	12.62
	H159	426	0.001	.....	.....	8.78	1.03	0.123	8.37
C_2	H129	705	0.025	0.326	9.165	9.32	1.74	0.188	9.26
C_3	H110	465	0.046	0.308	4.615	8.42	1.66	0.103	16.12
	H118	370	0.047	0.367	3.162	8.26	1.52	0.132	11.52
	H120	100	0.094	0.349	2.775	3.43	0.41	0.084	4.88
	H128	320	0.046	0.372	3.114	7.30	1.36	0.097	14.02
C_4	H 96	95	0.154	1.017	1.706	3.67	0.59	0.044	13.41
	H112	85	0.135	0.995	1.374	3.87	0.26	0.043	6.05
	H133	320	0.097	0.710	2.018	3.94	0.68	0.112	6.07
	H134	115	0.082	0.851	1.739	4.59	0.18	0.063	11.73
	H142	90	0.061	0.436	2.442	5.43	1.00	0.053	18.87
	H144	125	0.125	1.005	1.740	4.08	0.67	0.060	11.17
	H152	210	0.117	0.788	1.732	2.97	0.72	0.053	13.59
	H153	465	0.104	0.919	1.955	4.60	0.73	0.092	7.94
C_5	H 87	160	0.332	0.703	2.280	3.30	0.79	0.032	24.69
	H 94	120	0.245	0.839	2.123	3.05	0.56	0.071	7.89
C_6	H157	200	0.650	0.929	1.791	2.51	0.76	0.062	12.67

Table 3-4. D-Region and E-Region

	St. No.	Depth (m)	Md (mm)	Sk	S_o	Ignition loss(%)	C(%)	N(%)	C/N
D_1	H 56	258	0.015	1.029	13.42	8.11	1.04	0.129	5.42
	H 61	402	0.015	1.143	7.746	9.83	1.28	0.209	6.14
	H 64	348	0.016	1.371	7.206	9.96	1.40	0.142	9.86
D_2	H 55	100	0.135	0.427	6.787	5.93	0.66	0.101	6.54
	H 69	265	0.094	0.215	9.684	7.34	1.39	0.170	8.18
D_3	H 62	93	0.306	0.263	4.239	4.22	0.63	0.070	9.00
	H 63	88	0.375	0.374	3.141	3.01	0.36	0.074	4.87
D_4	H 36	352	0.083	0.686	8.595	5.89	0.84	0.126	6.67
	H 48	75	0.076	1.391	7.274	5.77	0.90	0.079	11.39
D_5	H 51	376	0.091	0.323	11.24	6.31	1.13	0.131	8.63
	H 57	460	0.072	0.655	8.324	8.04	1.13	0.195	5.80
D_6	H 49	98	0.321	0.090	7.390	4.92	0.65	0.052	12.50
	H 50	193	0.391	0.323	11.24	6.16	0.72	0.088	8.18
	H 52	415	0.347	0.054	8.07	6.91	1.11	0.087	12.76
	H 53	289	0.431	0.064	8.07	6.38	1.02	0.113	9.03
	H 60	453	0.295	0.067	8.51	6.92	0.95	0.202	4.70
E	H 42	541	0.055	0.088	14.83	6.82	1.18	0.136	8.68
	H 65	449	0.295	0.311	4.221	5.32	1.11	0.146	7.60
	H 76	79	0.072	0.119	12.41	5.77	0.64	0.036	17.78

THE VARIABILITY OF CATCHES IN VERTICAL PLANKTON HAULS*

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Introduction

The plankton net has long been in common use in the plankton collection for its great convenience, but in the strictly quantitative sampling the method of net haul has not always been considered the best.

Kokubo & Tamura (1931) concluded the inadequacies of the use of net for the quantitative studies in comparison with the results of pumping method. Kurashige (1931) showed by experiments that the different types of the net filter the water in different ratios. Aikawa (1934) experimented on the variability of collection by plankton net, obtaining less than 30% of coefficient of variation for total catch and less than 15% for the composition of catch. Yanagisawa (1934) compared the catches between those by net and those by Nansen bottle, and discussed limitation of use of the net in the quantitative studies. Egusa (1948) pointed out that for certain species of phytoplankton the amount of catch by net differs to a certain extent with the size of individual organisms contained in the catch. According to the analysis on the variability of catch of the sardine eggs by Ito & Nishimura (1954), the percentage standard deviation of a single observation varies from 35% to 55%.

In foreign countries Hensen (1887) making parallel vertical hauls of net, calculated the coefficient of variation in total catches of 10% to 15%. Lohmann (1905) made a further analysis of Hensen's data and found that the variation reaches to 20% to 30% in the individual number of particular species, but in certain species the variation may be much greater. Herdman (1921) made similar experiments, obtaining percentage deviation ranging from 14% to 121%. Gardiner & Graham (1925) carried out a series of oblique hauls of Petersen's young fish trawl and obtained the percentage standard deviation ranging from 27% to 54%. Gardiner (1931) made an observation on the variability of the International Standard Net and concluded that about 75% of hauls will not deviate by more than 33% from the mean, but that isolated deviations may reach 90%. Winsor & Walford (1936) experimented on the vertical hauls with several types of net and concluded that the obtained results can be accounted for reasonably well from two assumptions that (1) the organisms have random distribution in the water and that (2) the volume of water filtered varies in each haul. Ricker (1937) dealing with lake plankton pointed out that a large variance of catches is mainly due to irregular aggregation of organisms. Langford (1938) has extended the work of Ricker and stated that some species of organisms aggregate in a certain area, while others can be considered as

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making a random distribution. Winsor & Clarke (1940) carried out an observation on the variability to be expected in replicate hauls using the several types of nets and different ways of haul, finding that the variation of catches is due to true sampling variations on the one hand but also to inadequacies of sampling technique on the other hand. Silliman (1946) analyzed the samples of the eggs of Pacific pilchard, and found that most of the variability of egg counts is due to real differences in egg concentration and that a single count may be considered significantly different from another if it is less than one half or more than double the other. Barnes (1949, 1951a, 1951b with Marshall) made a series of extensive studies on the variability of plankton sampling. He assumed that the sampling variation is not entirely accounted for by the technical error but can be explained as caused by a non-random distribution of the organisms collected. Prasad, Bapat & Tampi (1952) calculated about 12.9% of the standard deviation of haul to haul variation in the horizontal plankton hauls.

At present in Japan regular zooplankton sampling recommended by the Fisheries Agency, Ministry of Agriculture, has usually been represented by one vertical haul from 150 metre depth at each hydrographic station using the so-called "Marutoku Net" (45 cm in mouth diameter, approximately 100 cm in length, made of Japanese grit gauze no. 54, having 0.327 mm of approximate mesh aperture); then only the results of a single haul at each station are dealt with. However, little attention has been paid to the variability of catches by this method. The present experiments have been undertaken to estimate the variability of vertical hauls with this net, so as to have statistically valid sense in analyzing the quantitative distribution of plankton sampled by this method.

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Experiments

SERIES I

The first series of experiment was made from 11 : 00 to 11 : 30 a. m. on August 7, 1953, at a position off the northwest of Otaru Harbour, west coast of Hokkaido. A series of five replicate hauls from 150 metre depth to the surface by the Standard Marutoku Net was made. The hauling velocity was kept as nearly at 100 cm per second

as possible. The calm water permitted the wire to be suspended almost vertically.

The plankton organisms which were numerous enough for use in analysis were divided into the following six major groups, viz, (1) large Copepoda (2) small Copepoda such as *Paracalanus*, *Clausocalanus* and *Oithona* (3) small Copepoda such as *Oncaea* and *Corycaeus* (4) Amphipoda (5) *Sagitta* and *Oikopleura* and (6) others. Table 1 gives the numbers of individuals of the six major groups sampled in each haul.

Table 1

No. of hauls	Large Copepoda	*Paracalanus Clausocalanus Oithona*	*Oncaea Corycaeus*	Amphipoda	*Sagitta Oikopleura*	Others	Total
1	331	7680	92	181	185	7	8476
2	407	6680	74	197	121	18	7497
3	333	4888	73	146	113	12	5565
4	383	5302	84	151	171	12	6103
5	424	6200	117	298	149	27	7215

In analyzing the variances, according to Winsor & Clarke (1940) when the standard deviations in the various groups of organisms are roughly proportional to the mean catch, it seems appropriate to use logarithmic values of the catch numbers; therefore logarithmic values are used instead of the actual numbers in the present analyses. The analysis of variance is given in table 2.

Table 2

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Hauls (H)	4	0.2235	0.0559
Species (S)	5	18.7666	3.7533
Residual (H × S)	20	0.4527	0.0226
Total	29	19.4428	

The mean square for hauls (H) is not significant when tested against interaction (H×S), so that it can be considered that identical populations are being sampled. Further analysis is made to determine the variance of a single observation. Here the logarithmic standard deviation is obtained for a single observation as $\sqrt{\frac{0.2235+0.4527}{4+20}} = 0.1679$, corresponding to a percentage standard deviation of 47%. Thus the 95% fiducial limits are roughly 46% and 217%.

Series II

As the ratio between the area of mouth and the total area of cloth in the Standard Marutoku Net is smaller than in the ordinary type of plankton net, it is expected that the net longer than the Marutoku Net would yield less variation in catches because of high filtration ratio. The net used in the experiment of Series II was lengthened to

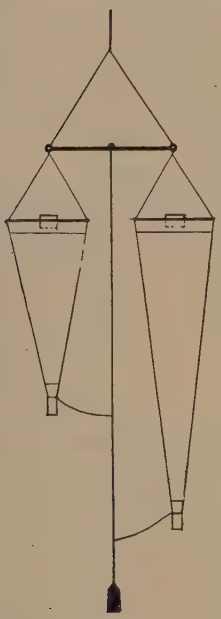

Fig. 1. Simultaneous haul of Standard Marutoku Net (left) and elongated net (right)

165 cm at the side. A net of standard pattern and an elongated one were connected to the wire end by being hung down at either end of a horizontal iron rod; thus both nets were lowered and raised simultaneously under quite the same conditions (fig. 1).

The experiment was made off Hakodate Harbour between 14 : 00-14 : 50 hours on November 11, 1954. Vertical hauls from 60 metre depth were repeated seven times. A moderate wind was blowing and the angle of the wire was roughly 25 degrees to the vertical line, and so the actual depth of sampling was about 54 metres. The velocity of haul was kept as constantly to be 130 cm per second as possible.

Two groups of animals were present in sufficient numbers for analysis; these are Copepoda and *Sagitta* (table 3).

Table 3

	1st haul		2nd haul		3rd haul		4th haul		5th haul		6th haul		7th haul	
	Long	Short	Long	Short	Long	Short	Long	Short	Long	Short	Long	Short	Long	Short
Large Copepoda	125	60	50	40	65	42	96	40	105	62	75	43	53	32
Small Copepoda	1320	1145	1410	815	1050	810	1040	965	1870	1520	2220	1080	2420	1410
Sagitta	296	220	224	208	268	220	248	220	560	410	360	252	456	290
Total	1741	1425	1684	1063	1383	1072	1384	1225	2535	1992	2655	1375	2929	1732

Copepoda is divided into two subgroups according to their body size, that is, one includes the large forms such as *Eucalanus* (immature), *Calanus helgolandicus* and *Centropages* and the other the small forms such as *Paracalanus*, *Clausocalanus*, *Oithona*, *Oncaea* and *Corycaeus*.

The analysis of variance for this set is given in table 4.

Table 4

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Main effects:			
Species (S)	2	12.9214	6.4607
Hauls (H)	6	0.3297	0.0550
Nets (N)	1	0.2656	0.2656
First order interactions:			
S×H	12	0.2597	0.0216
S×N	2	0.0345	0.0173
H×N	6	0.0079	0.0013
Second order interaction:			
S×H×N	12	0.0470	0.0039
Total	41	13.8658	

The values for S×N and H×N are not significant when tested against the second order interaction S×H×N, so that neither the percentage compositon of organisms caught by the nets during the experiment nor the proportion of catch of three groups together caught by the nets in the separate hauls can be considered to differ significantly. However, S×H is significant when tested against S×H×N (1% level), so that there is an indication of the changes in population sampled due to the passage of time or the shifting of the ship during the observation. The haul mean spuare (H) is not significant when tested against S×H in spite of being significant against the value of S×H×N, so that the high value of haul is considered to be due to the variation of S×H.

If the above results are accepted, they may be reasonably regrouped as in table 5.

Table 5

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	2	12.9214	6.4607
Nets	1	0.2656	0.2656
S×H	18	0.5894	0.0327
Remainder	20	0.0894	0.0045
Total	41	13.8658	

From the above table one gets

$$\sigma^2+2\sigma_{SH}{}^2=0.0327$$

whence

$$\sigma_{SH}{}^2=\frac{1}{2}\ (0.0327-0.0045)=0.0141$$

If one supposes that a particular group is picked at random, the variance of a single observation of either of the two nets is given by $\sqrt{\sigma_{SH}{}^2+\sigma^2}$, that is, 0.136. This is obtained from the logarithms of the catches; therefore as a percentage standard deviation,

or a coeffecient of variation, since

$$\log 1.37 = 0.136,$$
$$37\% = 137 - 100,$$

a value of 37% is obtained.

Then the 95% fiducial limits are calculated roughly as follows:

upper limit ..... $+ 0.136 \times 2 = 0.272 = \log 1.87.$

lower limit ..... $- 0.272 = \log \frac{1}{1.87} = \log 0.53.$

Thus one catch cannot be recognized as significantly different from another one unless it is less than 53% or more than 187% of its value.

Next, the analysis for each net is made separately. The analysis of variance for 165 cm net (longer net) is shown in table 6.

Table 6

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	2	5.9171	2.9586
Hauls	6	0.1941	0.0324
Residual	12	0.2092	0.0174
Total	20	6.3204	

The mean square of the hauls is not significant against the interaction. If one seeks the logarithmic standard deviation of a single observation one has $\sqrt{\frac{0.1941+0.2029}{6+12}} = 0.149$; from this one gets a percentage standard deviation of 41%.

The analysis of variance for the 100 cm net (standard net) is given in table 7.

Table 7

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	2	7.0388	3.5194
Hauls	6	0.1435	0.0239
Residual	12	0.0975	0.0081
Total	20	7.2798	

The mean square for hauls is again seen to be not significant. Here the logarithmic standard deviation of a single observation is $\sqrt{\frac{0.1435+0.0975}{6+12}} = 0.115$, corresponding to a percentage standard deviation of 30%.

It should be noted that the amount of water filtered through the cloth of net possibly varies for each of the hauls according to variable hauling technique. If the revolutions of the flow metre held in the centre of the mouth ring of the net indicate the true amount of water filtered, it may be possible to eliminate one factor of variability by checking the results of count using the readings of flow metre.

The analysis is made for the individual numbers which are corrected by flow metre readings. The analysis of variance of 165 cm net is given in table 8.

Table 8

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	2	5.9303	2.9652
Hauls	6	0.3236	0.0539
Residual	12	0.2039	0.0170
Total	20	6.4578	

The logarithmic standard deviation of haul to haul variation will be $3\sigma_H^2+\sigma^2=0.0539$, then $\sigma_H=0.1109$, corresponding to a percentage standard deviation of 26.2%. The logarithmic standard deviation of a single observation will be $\sqrt{\sigma_H^2+\sigma^2} = \sqrt{0.0123+0.0170} = 0.1711$; this corresponds to a percentage standard deviation of 48%.

Same analysis of the 100 cm net is given in table 9.

Table 9

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	2	6.6998	3.3499
Hauls	6	0.3339	0.0557
Residual	12	0.0676	0.0056
Total	20	7.1013	

The logarithmic standard deviation of haul to haul variation is obtained as $3\sigma_H^2+\sigma^2 = 0.0557$, so $\sigma_H=0.1292$, which corresponds to a percentage standard deviation of 34.7%. The value of logarithmic standard deviation of a single observation is obtained as $\sqrt{\sigma_H^2+\sigma^2} = \sqrt{0.0167+0.0056} = 0.1493$, corresponding to a percentage standard deviation of 41%. Here the values of variation are rather increased when the count is corrected by flow metre readings over that in the case without such correction. So far as the above results are concerned, the use of readings of flow metre in vertical haul seem not to increase the validity of estimation.

The ratio of catches of 165 cm net to those of 100 cm net will next be considered. The mean of the differences of the logarithms of both catches is 0.1623, corresponding to an actual ratio of the catches of 1.45. The variance of the logarithm of this ratio is $2 \times \frac{0.03274}{7\times3} = 0.003118$, giving a standard deviation for the logarithm of 0.055. Hence 99% fiducial limits are gotten as $0.1623 \pm 3 \times 0.055 = \bar{1}.9973 \sim 0.3273$. Then the actual ratios will lie between 0.99 and 2.12. On the other hand, the ratio of the filtering area (area of gauze) of 165 cm net to area of 100 cm net is 1.65, which is a little larger than the actual ratio of catches observed (1.45).

SERIES III

The experiments were made off Cape Esan, south coast of Hokkaido, from 21 : 00 to 21 : 25 hours on October 20, 1954. A pair of different types of Marutoku Nets, viz., 165 cm and 100 cm in length, were hauled vertically three times in the same way as in the previous experiments. The speed of hauls was kept about 80 cm per second. Six groups of animals were taken in sufficient number for analysis, viz., large Copepoda (*Calanus helgolandicus*, *Eucalanus* spp., *Euchaeta marina*, *Metridia lucens* and *Calanus tenuicornis*); medium sized Copepoda (*Paracalanus*, *Clausocalanus*, *Oithona*, *Oncaea* and *Corycaeus*); Amphipoda (mainly consisted of *Themisto* sp.); Euphausiacea (consists of *Euphausia* and *Thysanoessa*); *Sagitta* and *Oikopleura* (table 10).

Table 10

	1st haul		2nd haul		3rd haul	
	Long	Short	Long	Short	Long	Short
Large Copepoda	576	460	348	146	448	320
Small Copepoda	2160	960	1920	1200	3040	1040
Euphausiacea	62	62	59	50	51	23
Amphipoda	11	12	8	1	18	6
Sagitta	777	438	723	397	521	228
Oikopleura	768	80	192	132	352	96
Total	4354	2012	3250	1926	4430	1713

The analysis of variance for these hauls is given in table 11.

Table 11

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Main effects:			
Species (S)	5	20.7199	4.1440
Hauls (H)	2	0.2554	0.1277
Nets (N)	1	0.9934	0.9934
First order interactions:			
S × H	10	0.5186	0.0519
S × N	5	0.0819	0.0164
H × N	2	0.0038	0.0019
Second order interaction:			
S × H × N	10	0.7727	0.0773
Total	35	23.3457	

It is clear that mean squares of hauls and each of the first order interactions do not differ significantly. Therefore the data on analysis of variance may be regrouped in table 12.

Table 12

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	5	20.7199	4.1440
Nets	1	0.9934	0.9934
Remainder	29	1.6324	0.0563
Total	35	23.3457	

The mean squares for nets and remainder show rather more high values than in Series II. An estimate of the logarithmic standard deviation of a single observation is 0.2372, corresponding to a percentage standard deviation of 72%; then 95% fiducial limits are calculated as 33% and 298%.

An analysis is made for long (165 cm) and short (100 cm) nets separately. The analysis of variance is given in tables 13 and 14 respectively.

Table 13

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	5	10.0814	2.0163
Hauls	2	0.0996	0.0498
Residual	10	0.3202	0.0320
Total	17	10.5012	

Table 14

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	5	10.7205	2.1441
Hauls	2	0.1762	0.0881
Residual	10	0.9544	0.0954
Total	17	11.8511	

In both tables the mean squares for hauls are not significant when tested against the residual. From table 13 the logarithmic standard deviation of a single observation for the long net is 0.186, or a percentage standard deviation of 53%. From table 14 the logarithmic standard deviation for short net is 0.3069 and the percentage standard deviation is 102%. The values of variation are also higher than those of Series II.

Again, it may be needful to consider the variation of a single observation of each net on the counts which are corrected by the readings of revolution of the flow metre. The analysis of variance for the long and the short nets is given in tables 15 and 16.

Table 15

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	5	10.1982	2.0398
Hauls	2	0.0947	0.0474
Residual	10	0.2118	0.0212
Total	17	10.5047	

Table 16

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	5	10.7503	2.1501
Hauls	2	0.1282	0.0641
Residual	10	0.8441	0.0844
Total	17	11.5944	

The mean squares for hauls are not significant when tested against the values of residual in each table. The logarithmic standard deviation of a single observation for long net is 0.159, giving a percentage standard deviation of 44%; that for a short net is gotten as 0.248 which corresponds to a percentage standard deviation of 92%.

The ratio for the catches of the long net to those of the short net is 0.3322 in logarithmic value, corresponding to an actual ratio of 2.15. The variance of this ratio is 0.0063, which corresponds to a standard deviation of 0.079; then 99% fiducial limits are 0.0952 and 0.5692, and therefore, the actual ratios will lie between 1.25 and 3.71. Although the ratio of area of filtering cloth of the long net to that of the short net (1.65) is smaller than the above actual ratio of catches between both nets, it lies within the three standard deviation limits of the ratio of catches.

Series IV

This series was taken from the same depth half an hour after Series III the duration of the take being twenty-five minutes. The same abundant species were grouped into six as in Series III (table 17). The velocity of haul was kept 100 cm per second, somewhat faster than in the previous series.

Table 17

	1st haul		2nd haul		3rd haul	
	Long	Short	Long	Short	Long	Short
Large Copepoda	410	300	400	272	390	335
Small Copepoda	4160	1440	2880	1620	2900	2050
Euphausiacea	48	32	87	72	81	98
Amphipoda	23	12	8	4	9	7
Sagitta	368	283	367	324	435	173
Oikopleura	96	80	272	128	275	110
Total	5105	2147	4014	2420	4090	2773

Analysis of variance runs (table 18):

Table 18

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Main effects:			
Species (S)	5	19.7526	3.9505
Hauls (H)	2	0.0143	0.0072
Nets (N)	1	0.2971	0.2971
First order interactions:			
S × H	10	0.5222	0.0522
S × N	5	0.0765	0.0153
H × N	2	0.0038	0.0019
Second order interaction:			
S × H × N	10	0.1186	0.0119
Total	35	20.7851	

The values for both H and first order interactions are not significant when tested against the value of second order interaction. It seems therefore that there was not possible any change in the population during the period of sampling. Here the data from the above table may be regrouped into following one (table 19).

Table 19

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	5	19.7526	3.9505
Nets	1	0.2971	0.2971
Remainder	29	0.7354	0.0254
Total	35	20.7851	

From this table the logarithmic standard deviation of 0.159 is gotten, corresponding to a percentage standard deviation of a single observation of 44%; then 95% fiducial limits are 48% and 208%.

Secondly calculations may be made for two different nets independently. The analysis of variance for the long and the short nets is shown in tables 20 and 21 respectively.

Table 20

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	5	10.0990	2.0198
Hauls	2	0.0024	0.0012
Residual	10	0.3246	0.0325
Total	17	10.4260	

Table 21

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	5	9.7301	1.9460
Hauls	2	0.0157	0.0079
Residual	10	0.3162	0.0316
Total	17	10.0620	

As to both of the nets the mean squares of hauls are not significant when tested against the interactions. Here the logarithmic standard deviation for the 165 cm net is 0.165, corresponding to a percentage standard deviation of 46%. Again, the logarithmic standard deviation of 0.166 is gotten for the 100 cm net, giving a percentage standard deviation of 46%.

Similarly the analysis on the counts corrected by the flow metre readings is given in tables 22 and 23.

Table 22

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	5	10.0215	2.0043
Hauls	2	0.0115	0.0058
Residual	10	0.3174	0.0317
Total	17	10.3504	

Table 23

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	5	9.4519	1.8904
Hauls	2	0.0427	0.0214
Residual	10	0.2898	0.0290
Total	17	9.7844	

The values for hauls are also not significant against the interactions in each net. From table 22, the logarithmic standard deviation is 0.165, which corresponds to a percentage standard deviation of 46%. From table 23, the logarithmic standard deviation is 0.166, which gives a percentage standard deviation of 46%. Thus the percentage standard deviation for a single observation of both long and short nets does not vary by the correction by flow metre readings.

The mean of the differences of the logarithms for the catches of long and short nets is 0.1816, corresponding to an actual ratio of 1.52. The variance in logarithm of this ratio is 0.0028, giving a standard deviation for logarithm 0.052; then 99% fiducial limits 0.0226 and 0.3406 as lower and upper limits which correspond to the actual ratios of 1.05 and 2.19.

SERIES V

That there happens a loss in catch in the vertical divided hauls using the Nansen closing device has been noticed by the experiments of Barnes (1949). He pointed out that the use of Kofoid's cone net would tend to reduce the loss in catch. The junior author and his colleague (Nishizawa & Anraku, unpublished) have made direct visual observation on the flow of water around the mouth of the net by the aid of the Underwater Observation Chamber "Kuroshio" (Inoue *et al.*, 1953). They actually saw that the water as coloured by the dissolving potassium permanganate in the bag set in the net actually flowed up from the mouth of the net when the net was suddenly stopped in the way of vertical hauls. Change in velocity of hauling a plankton net is expected to happen frequently during the work at sea; especially when the net is closed.

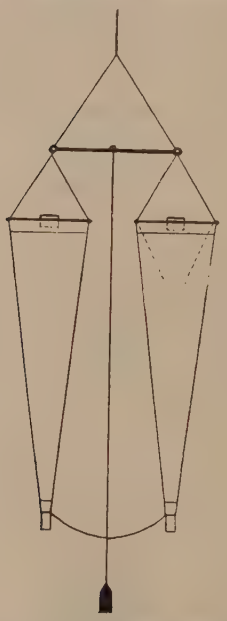

Fig. 2. Simultaneous haul of net without inner cone (left) and net with inner cone (right)

An inner cone 7 cm in lower mouth diameter and 31 cm in side length was designed; it was fastened inside the mouth margin of the 165 cm net. Two nets, one with inner cone and the other without, both of the same size, were hung at either end of the horizontal iron rod in the same way as in the experiment of Series II (fig. 2). Then the nets were hauled repeatedly to estimate the variation of catches of each net.

The experiments were made from 2 : 30 to 3 : 00 hours on October 21, 1954, off Cape Esan, south coast of Hokkaido. The speed of hauls was kept 80 cm per second. The net hauls were made three times and the counts of organisms were made on the six major groups, viz., large Copepoda, small Copepoda, Amphipoda, Euphausiacea, *Sagitta* and *Oikopleura* (table 24).

Table 24

	1st haul		2nd haul		3rd haul	
	with cone	without cone	with cone	without cone	with cone	without cone
Large Copepoda	264	584	80	252	84	888
Small Copepoda	1360	5120	684	4050	840	7750
Euphausiacea	31	83	9	87	7	111
Amphipoda	3	11	1	7	3	20
Sagitta	90	348	75	443	61	910
Oikopleura	16	112	8	96	24	545
Total	1764	6258	857	4935	1019	10224

The results of the analysis of variance is given in table 25.

Table 25

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Main effects:			
Species (S)	5	23.9431	4.7886
Hauls (H)	2	0.2207	0.1104
Nets (N)	1	5.2212	5.2212
First order interactions:			
S × H	10	0.5716	0.0572
S × N	5	0.0725	0.0125
H × N	2	0.4498	0.2249
Second order interaction:			
S × H × N	10	2.3997	0.2400
Total	35	32.8786	

The mean squares for hauls and the first order interactions are not significant when tested against the second order interaction, so the above table may be grouped again as follows (table 26):

Table 26

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	5	23.9431	4.7886
Nets	1	5.2212	5.2212
Remainder	29	3.7143	0.1281
Total	35	32.8786	

Here the variability of a single observation is obtained in logarithmic value as 0.357, corresponding to a percentage standard deviation of 127%, and 95% fiducial limits lie as wide as 19% and 518%.

Next, it may be interesting to compare the variability of catches of the two nets. Accordingly the analysis of variance is made independently on the samples from the two kinds of nets. An analysis of data from the nets with or without cone is given in tables 27 and 28.

Table 27

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	5	12.1613	2.4323
Hauls	2	0.1736	0.0868
Residual	10	0.7550	0.0755
Total	17	13.0899	

Table 28

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	5	11.8543	2.3709
Hauls	2	0.4969	0.2485
Residual	10	0.7132	0.0713
Total	17	12.5675	

The value of H of each net is not significant against the residual. For the cone net the logarithmic standard deviation of 0.278 is obtained which corresponds to a percentage standard deviation of 90%, and also the value of 0.317 is gained for ordinary net (without cone) which corresponds to 108% of percentage standard deviation.

Again, the data of both nets may be analyzed after the correction by the flow metre readings is made. The results are given in tables 29 and 30.

Table 29

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	5	12.5215	2.5043
Hauls	2	0.2900	0.1450
Residual	10	1.1197	0.1200
Total	17	13.9312	

Table 30

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	5	11.8297	2.3659
Hauls	2	0.4480	0.2240
Residual	10	0.2120	0.0212
Total	17	12.4897	

In this case also no significant relation is observed between the mean square for hauls and for interaction in table 29; then the logarithmic standard deviation of 0.342 is obtained for the cone net, which corresponds to a percentage standard deviation of 120% of a single observation. From table 30, the value of hauls is significant, whence the logarithmic standard deviation of haul to haul variation is gotten as 0.183, which corresponds to a percentage standard deviation of 52%. Again, the values of 0.234 and 72% are gotten for a single observation of the ordinary net.

The mean of the differences of catches of either net is 0.7616 in logarithmic value, corresponding to an actual ratio of 5.78; the variance of logarithmic value will be 0.0142, and this will give 99% fiducial limits of 0.4016 and 1.1216, which correspond to the actual ratios of 2.52 and 13.20.

SERIES VI

The experiments comprised six hauls just as in Series V. The hauls were made during the daytime (10 : 50 – 12 : 05) on November 17, 1954, in Hakodate Bay, south coast of Hokkaido. Three hauls were made vertically from a depth of 50 metres to the surface at speed of 95 cm per second, and in the other three hauls the nets were raised from 50 metre depth to 10 metre depth, then the haul was stopped for two seconds after which the nets were raised to the surface. The wire carrying the nets was perpendicular throughout the observation. Small Copepoda and *Sagitta* were present in sufficient number for analysis (tables 31 and 32).

Table 31

	1st haul		2nd haul		3rd haul		4th haul		5th haul	
	with cone	without cone	with cone	without cone	with cone	without cone	with cone	without cone	with cone	without cone
Small Copepoda	87	131	444	1024	131	832	145	1450	870	1450
Sagitta	4	3	31	66	32	45	18	68	55	84
Total	91	134	475	1090	163	877	163	1518	925	1534

Table 32

	1st haul		2nd haul		3rd haul		4th haul		5th haul	
	with cone	without cone	with cone	without cone	with cone	without cone	with cone	without cone	with cone	without cone
Small Copepoda	1305	1124	1088	1305	104	656	53	330	138	1128
Sagitta	70	74	76	141	22	68	14	45	27	250
Total	1375	1198	1164	1446	126	724	67	375	165	1378

(a) continuous hauls

The analysis of variance for table 31 is given in table 33.

Table 33

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Main effects:			
Species (S)	1	7.0567	7.0567
Hauls (H)	4	3.0951	0.7738
Nets (N)	1	0.6698	0.6698
First order interactions:			
S × H	4	0.1592	0.0399
S × N	1	0.1066	0.1066
H × N	4	0.3272	0.0818
Second order interaction:			
S × H × N	4	0.0717	0.0179
Total	19	11.4863	

In this table the mean square for hauls is significant when tested against the second order interaction. All of the first order interactions are not significant when tested against the second order interaction, so the above table may reasonably be summarized as below (table 34):

Table 34

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	1	7.0567	7.0567
Hauls	4	3.0951	0.7738
Nets	1	0.6698	0.6698
Remainder	13	0.6647	0.0511
Total	19	11.4863	

Here the logarithmic standard deviation of haul to haul variation is obtained as 0.409, corresponding to a percentage standard deviation of 156%.

Now the logarithmic standard deviation for a single observation is 0.481, corresponding to a percentage standard deviation of 202%, then 95% fiducial limits are 10% and 917%.

Then the separation of the original data is made according to the presence or absence of the inner cone of the nets. The analysis of variance for the cone net is given in table 35 and that of the ordinary net (without cone) in table 36.

Table 35

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	1	2.7144	2.7144
Hauls	4	1.2907	0.3227
Residual	4	0.1672	0.0418
Total	9	4.1723	

Table 36

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	1	4.4489	4.4489
Hauls	4	2.1317	0.5329
Residual	4	0.0636	0.0159
Total	9	6.6442	

Here the logarithmic standard deviation of haul to haul variation for cone net is 0.347, which corresponds to a percentage standard deviation of 137%; and the logarithmic standard deviation of a single observation is 0.426, corresponding to a percentage standard deviation of 167%. As the standard deviation in the logarithm for haul to haul variation of the ordinary net the value is 0.508, which corresponds to a percentage standard deviation of 222%, while the logarithmic standard deviation for a single observation is 0.523, which corresponds to a percentage standard deviation of about 233%.

The analysis of variance is made next concerning the data which are corrected by

the readings of revolutions of flow metre. The analysis of the cone net and the ordinary net is given in tables 37 and 38 respectively.

Table 37

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	1	2.7773	2.7773
Hauls	4	1.3121	0.3280
Residual	4	0.1847	0.0462
Total	9	4.2741	

Table 38

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	1	3.7826	3.7826
Hauls	4	2.6589	0.6647
Residual	4	1.2345	0.3086
Total	9	7.6760	

For the cone net the logarithmic standard deviation of haul to haul variation is obtained as 0.375, corresponding to a percentage standard deviation of 137%; and the logarithmic standard deviation of a single observation is 0.433 which corresponds to a percentage standard deviation of 171%. For the ordinary net values of 0.697 and 397% are obtained for a single observation.

Next a comparison of catches of both types of net is made. The mean of the differences of the catches is 0.446, which corresponds to an actual ratio of 2.79. The variance of this ratio as a logarithm is 0.1548, corresponding to a standard deviation of 0.393, and so 99% fiducial limits are $\bar{1}.237$ and 1.545, which correspond to the actual ratios of 0.24 and 35.08.

(b) hauls with a stop on the way

Regarding the individual numbers in table 32 the analysis is made as in table 39.

Table 39

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Main effects:			
Species (S)	1	4.0952	4.0952
Hauls (H)	4	1.7215	0.4304
Nets (N)	1	1.1377	1.1377
First order interactions:			
S × H	4	0.2177	0.0544
S × N	1	0.0035	0.0035
H × N	4	0.6157	0.1539
Second order interaction:			
S × H × N	4	0.0549	0.0137
Total	19	7.8462	

The mean square for hauls is significant when tested against the second order interaction. The logarithmic standard deviation of haul to haul variation is 0.242, then a percentage standard deviation of 74% is obtained. Both S×H and S×N are not significant against S×H×N, but H×N is significant. However, the mean squares of hauls and nets are not significant when tested against H×N. So that, data in the above table may be reasonably grouped again as follows (table 40):

Table 40

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	1	4.0952	4.0952
H×N	9	3.4749	0.3861
Remainder	9	0.2761	0.0306
Total	19	7.8462	

The logarithmic standard deviation for hauls is 0.456, which corresponds to a percentage standard deviation of 186%, hence 95% fiducial limits are gotten as 15% and 817%.

The analysis of variance for each net is given in tables 41 and 42.

Table 41

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	1	1.9272	1.9272
Hauls	4	1.8198	0.4550
Residual	4	0.1977	0.0494
Total	9	3.9447	

Table 42

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	1	2.1715	2.1715
Hauls	4	0.5174	0.1294
Residual	4	0.0749	0.0187
Total	9	2.7638	

Regarding the haul to haul variation, the logarithmic standard deviation of 0.450 for the cone net, which equals to a percentage standard deviation of 182%; while the logarithmic standard deviation of a single observation is 0.502, corresponding to a percentage standard deviation of 217%. On the other hand, the values of haul to haul variation for the ordinary net are given as 0.235 and 71%; and those of a single observation are 0.272 and 87%.

The analysis for either net after making correction by flow metre readings is given in tables 43 and 44 respectively.

Table 43

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	1	1.9360	1.9360
Hauls	4	1.3662	0.3416
Residual	4	0.1978	0.0494
Total	9	3.5000	

Table 44

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Species	1	2.1996	2.1996
Hauls	4	0.6174	0.1544
Residual	4	0.0786	0.0197
Total	9	2.8956	

Here the logarithmic standard deviation of haul to haul variation of the cone net is 0.382, corresponding to a percentage standard deviation of 141%, and those of a single observation will be 0.431 and 170%. The values of 0.259 and 81% are gotten for haul to haul variation, and 0.295 and 97% for a single observation of the ordinary net.

The mean of differences of catches for both nets is 0.478 in logarithmic value which corresponds to an actual ratio of 3.01. Then the variance of this logarithmic value is 0.0861, corresponding to a standard deviation of 0.29, hence 99% fiducial limits are $\bar{1}.608$ and 1.348. They correspond to the actual ratios of 0.41 and 22.29.

Discussion

The results of the present studies may be conveniently summarized as shown in table 45.

Table 45

Series of Experiment	Percentage Standard Deviation of a single observation of either of two nets (see p.156)	P.S.D. of a single observation of each net								Ratio of catches between two nets	
		without correction by flow metre				corrected by flow metre					
		100 cm net	165 cm net	165 cm net with inner-cone	165 cm net without inner-cone	100 cm net	165 cm net	165 cm net with inner-cone	165 cm net without inner-cone	Ratio of catch obtained	99% fiducial limits of the ratio
I		47									
II	37	30	41			41	48			1.45	0.99~ 2.12
III	72	102	53			92	44			2.15	1.25~ 3.71
IV	44	46	46			46	46			1.52	1.05~ 2.19
V	127			90	108			120	72	5.78	2.52~13.20
VIa	202			269	233			171	397	2.79	0.24~35.08
VIb	186			217	87			170	97	3.01	0.41~22.29

The percentage standard deviations of a single observation for three types of net (100 cm long net, 165 cm long net and 165 cm long net with the inner cone) in each series are ranged from 30% to 269%. On the other hand, according to the previous estimates (Winsor & Walford, 1936; Winsor & Clarke, 1940; Barnes, 1949; Prasad *et al.*, 1952; Ito & Nishimura, 1954, etc.) the standard deviation of a single observation in the vertical hauls made under good conditions has been reported from 40% to 50% in the mean. In spite of the fact that present experiments have been carried out with special attention to the treatment of samples, the values of standard deviation were often larger than those of the previous investigations. Both in Series II and IV, when the nets are hauled at a speed of more than 100 cm per second, the order of variation is equivalent to the preceding works. However, the values in the samplings in Series VI in which the hauling velocity is 95 cm per second are several times of them. The first order interaction S×H is not significant when tested against the value of the second order interaction S×H×N in all of the experiments except in Series II, so that the high values of variations obtained are considered to be not caused by the change of percentage in composition of population. The factor responsible for the high values of variations is supposed to be in some technical matter. According to the experiments made by Nishizawa & Anraku (unpublished) it has been shown that the inflow of water into the mouth of the plankton net varies to a certain extent even when the hauling velocity has only slightly changed during a haul. The speed that gives the steady inflow of the water to the net has been observed to lie at 100 cm per second or more. In the present experiments the speed of hauls has ranged from 80 to 130 cm per second. The experiments made at comparatively low speed of hauls (Series III, V, VI) yielded generally high values of variations. The variation of a single observation might be reduced to 30 to 50% if the nets were hauled carefully at a speed of 100 cm per second or a little more. This minimum variation is considered mainly due to the local swarming of organisms.

The variations are not always decreased when the counts are corrected by flow metre readings. It is suggested that so far as concerns the present experiments, the adjustment of amount of water by readings of flow metre did not always yield more valid results.

The first order interactions (S×N) for tables 11, 18, 25 and 33 are not significant when tested against the values of the second order interaction respectively, then there is general indication that both 165 cm and 100 cm Marutoku Nets appear to catch all the groups here discussed in the same proportion, and this is also the case between the cone net and ordinary net. It may therefore be supposed that under the condition of the present investigation differential selection for particular species by types of net does not occur.

The means of the ratios for the catches of both 165 cm and 100 cm nets in Series II, III and IV are 1.45, 2.15 and 1.52 respectively, and 99% fiducial limits ranged from

0.99 to 3.71. The ratios in Series II and IV for the catches are smaller than the ratio (1.65) of the cloth area of both nets, while the ratio for catches in Series III is a little larger than the ratio of the cloth area but lies within the 95% fiducial limits. Thus, any proportional increase of catch against the increase of the area of filtering cloth cannot always be expected by using the long net. In addition to the above facts just mentioned, the variations of catches of the long net are not always smaller than those of the short net.

The cone of cloth attached inside the net is expected to prevent the outflow of the content in the net when it is suddenly stopped or hauled at variable speeds. The ratio of catches for both nets used in Series VIa (non stop) is smaller than that in VIb (stop). This indicates that the inner cone is somewhat useful for retaining the catch inside the net when the haul is stopped on the way. In the experiment of Series VI, the data were rearranged for comparing the catches of the net when it was not stopped during the hauls with that of the same net when it was stopped; then the ratios are calculated as follows: The mean of the difference of catches in logarithm is 0.246 for the cone net, corresponding to an actual ratio of 1.76, then 99% fiducial limits are roughly 0.595 and 5.16, while the mean of the difference of the ordinary net is 0.038 which corresponds to an actual ratio of 1.09; here are found 99% fiducial limits of 0.437 and 2.72. According to this calculation the usefulness of inner cone is not proved. Thus the effectiveness of inner cone is indicated to be not always significant.

Summary

(1) The variability of catches by vertical hauls with the Standard Marutoku Net and the similar types was calculated by repeated samplings at sea.

(2) In the experiment of Series I the percentage standard deviation of a single observation of a Standard Marutoku Net is calculated to be 47%.

(3) In Series II, III and IV the standard deviation of haul to haul variation is zero in both Standard Marutoku Net (side length 100 cm) and elongated net (side length 165 cm). The values for a single observation range from 30% to 102% in the standard net, and from 41% to 53% in the elongated net. It seems therefore that the values of long net are not always smaller than those of the short one.

(4) It might be expected, that the sampling variation is due largely to the local swarming (statistically non-random distribution) of the organisms.

(5) The proportion of major groups of organisms caught by the different types of nets does not vary. It is therefore indicated that under the conditions of the present investigation no differential selection with the size or shape of net is observed.

(6) The amount of catch is not always proportional to the cloth area of long and short nets having the same mouth diameter. The ratios of the mean in catches

of long net to short net are 1.45, 2.15 and 1.52 (ratio of filtering cloth area 1.65), and 99% fiducial limits of ratios range 0.99 to 3.71 (Series II, III, IV).

(7) The effectiveness of inner cone of the net which is expected to be useful in preventing the outflow of the content was tested, but significantly positive results were not obtained.

Literature cited

Aikawa, H. (1934). On the reliability of plankton-net. *Bull. Jap. Soc. Sci. Fish.* 3(1-6), 331-345. (in Japanese).

Barnes, H. (1949). Statistical study of the variation in vertical plankton hauls, with special reference to the loss of the catch with divided hauls. *Jour. Mar. Biol. Assoc.* **28**(2), 429-446.

———— (1951a). Horizontal plankton hauls. *Jour. du Cons.* **17**(2), 133-139.

———— & Marshall, S. M. (1951). On the variability of replicate plankton samples and some applications of "contagious" series to the statistical distribution of catches over restricted periods. *Jour. Mar. Biol. Assoc.* **30**(2), 233-263.

Egusa, S. (1948). The seasonal variation of size in phytoplankton and the reliability of net-collection. *Bull. Jap. Soc. Sci. Fish.* **15**(1), 78-82. (in Japanese).

Gardiner, A. C. (1931). The validity of single vertical hauls of the international net in the study of the distribution of the plankton. *Jour. Mar. Biol. Assoc.* **17**(2), 449-472.

———— & Graham, M. (1925). The working error of Petersen's young fish trawl. *Fish. Invest.* Ser. 2, **8**(3), 1-8.

Hensen, V. (1887). Ueber die Bestimmung des Planktons. 5. *Ber. Komm. wiss. Unters. deut. Meer.* 1-108.

Herdman, W. (1921). Variation in successive vertical plankton hauls at Port Erin. *Proc. Trans. Liverpool Biol. Soc.* **35**, 161-174.

Inoue, N., Sasaki, T. & Oaki, R. (1953). "Kuroshio" undersea observation chamber. *Rec. Oceanogr. Wks. Jap.*, N. S. **1**(1), 52-62.

Ito, S. & Nishimura, S. (1954). [Fundamental studies on the spawning of sardine. Validity of vertical net haul for egg sampling. Sardine investigations in the Japan Sea.] *Bull. Japan Sea Reg. Fish. Res. Lab.* (8), 33-40. (in Japanese) (mim. rept.).

Kokubo, S. & Tamura, T. (1931). A quantitative investigation of the plankton of Aomori Bay, as studied comparatively by pump and net collection. *Sci. Rep. Tohoku Imp. Univ.*, Ser. 4, biology, **6**(3), 491-531.

Kurashige, H. (1932). [On the comparative quantitative determination of plankton by various types of nets.] *Kaiyojiho (Jour. Oceanogr., Imp. Mar. Obs., Kobe, Japan)*, 3(2), 430-437. (in Japanese).

Langford, R. R. (1938). Diurnal and seasonal changes in the distribution of the limnetic crustacea of Lake Nipissing, Ontario. *Publ. Ontario Fish. Res. Lab.* **56**, 1-142.

Lohmann, H. (1903). Neue Untersuchungen über den Reichthum des Meeres an Plankton und über die Brauchbarkeit der verschiedenen Fangmethoden. *Wiss. Meeresunt., Kiel*, N. F. 7, 1-88.

Prasad, R. R., Bapat, S. V. & Tampi, P. R. S. (1952). Observations on the distribution of plankton at six inshore stations in the Gulf of Manaar. *Jour. Zool. Soc. India* **4**(2), 141-151.

Ricker, W. E. (1937). Statistical treatment of sampling processes useful in the enumeration of plankton organisms. *Arch. Hydrobiol.* **31**, 68–84.

Silliman, R. P. (1946). A study of variability in plankton tow-net catches of Pacific pilchard (*Sardinops caerulea*) eggs. *Jour. Mar. Res.* **6**(1), 74–83.

Winsor, C. P. & Clarke, G. L. (1940). A statistical study of variation in the catch of plankton nets. *Ibid.* **3**(1), 1–34.

———— & Walford, L. A. (1936). Sampling variations in the use of plankton nets. *Jour. du Cons.* **6**(2), 190–204.

Yanagisawa, T. (1934). 〔Daily change of plankton off Suma, Hyogo Pref., and the comparison of method of collection by the plankton net and the Nansen-bottle.〕 *Kaiyokisyodai-Iho, Imp. Mar. Obs., Kobe, Japan*, **72**, 1-11. (in Japanese).

源五郎鮒の鱗に現われる年輪に就いて

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Study on the Annulus of the Scale of the "Gengoro-buna", One of the Races of *Carassius auratus*

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Abstract

The age of a fish can be assessed by the annuli which are seen on the scale of that fish. But whether the annuli can be the signs of the fish age must be proven by experimental data on each species of fishes, though it is reasoned that the annuli generally indicate the age of that fish, on the basis of indirect evidences too.

This report describes studies on the scale, with special reference to the characters of the annuli of the "Gengoro-buna," one of the races of *Carassius auratus*. The specimens for the study are obtained out of the fish hatched from the artificially fertilized eggs and reared in fish-ponds.

The results obtained are summarized as follows:

1. One clear winter ring is regularly formed between the first and second summer zone.
2. This can be recognized as a true annulus.
3. Construction of the annulus by the circuli is different between the anterior and lateral (dorsal and ventral) parts of the annulus.
4. The anterior part is simple and of one type, but the lateral part is complex and there can be recognized a few types —A, B and C type.
5. The time of the formation of the annulus is considered to be the spring at the time when the growth of the scale begins.
6. Scales of some specimens have false annuli.
7. It is very difficult to distinguish a well-developed false annulus from the true one.
8. Investigation was made on how to distinguish false annuli from true ones.

I　緒　言

鱗によつて其の魚齢を査定することは，遠く1873年仏の Baudelot に創まると云われて居るが[1]，1897年に至り独の Hoffbauer[2] が，年齢の判明して居る鯉の鱗面の輪紋につき吟味し，之によつて鯉の年齢を判定することが出来ることを発表した。其の後魚の年齢査定に関する研究が盛んになつて来たが，最近は各種の淡・鹹水魚につき鱗による魚齢の査定が広く行はれ，単に其の魚の年齢を知るばかりでなく，scale method として，魚の成長度，生活史，更に水産資源の調査研究の上にも非常に役立つ様になつて来た。

然るに魚鱗によつて其の魚齢を査定することが出来ると云うことは，鱗の annuli（年輪）は毎年規則正しく形成されると云う仮定に立脚して居るもので，其の魚の鱗の所謂年輪がはたして其の魚齢を表わす標となるか否かと云うことは，各魚種につき実験的に証明されなければならない事である[3]。年輪の確実性については，色々な推論が下されては居るが，夫々の魚に於て実験的証明を欠いて居ることは，scale method が彼是批評を受ける弱点ともなる訳である[4]。

鮎は秋生れ，普通翌秋産卵までの寿命であることは周知の事であるが，安田[5] の調査によると，6月以後に漁獲された本邦各地産の鮎に於ては，多くの場合，其の鱗に二つの年輪類似の輪紋が見られると報告し，又堀井[6] は琵琶湖の小鮎が，琵琶湖に注ぐ川に天然に遡上して成体になつたもの及び小鮎が琵琶湖以外の川

に移殖されて其処で成体になつたものにつき其の鱗を観察し，両者共其の focus に近い処に circuli の密な部分のあることを認め，更に又鱗の周縁に於て circuli の間隔が稍狭くなつて居ると報じて居る。斯くの如く鮎の鱗には普通内側に1～2本の輪紋が認められる様であるが，之は鮎の生活史から考えても，直ちに之を年輪として取り扱うべきものでない事は明らかである。

鮎の鱗に特にかかる輪紋の出現することを明にせずに，其の年齢を鱗によつて査定する時には，かつて Jordan & McGregor[7] が日本産鮎の年齢を1才乃至4才であると判定した様な誤りも起つて来るわけである。

北海道の大沼には昭和2年琵琶湖から其の名産源五郎鮒が移殖せられ，其の後其の繁殖が旺盛で，毎年数千貫の生産を挙げる様になつた。其の大なるものは全長40cm内外に成育し，誠に見事なものである。此の鮒の鱗には比較的判然たる所謂年輪が現われて居り，其の魚齢を査定することが出来る。其の大なるものは8才内外に達して居る様である。之は松井[5]が本邦各地産鮒の材料につき調査した最高の年齢と一致して居る。

然し此の源五郎鮒の鱗の所謂年輪が，はたして真の年輪であるか否かは未だ実験的に証明されてない様である。以下に発表するものは源五郎鮒の鱗に現われる紋様，特に年輪の成生について実験観察したものである。本研究は未だ実験上欠くるところがあるが，今までに得た実験材料を取りまとめ報告することにした。

本実験の施行に当つては，其の採卵等については大沼漁業協同組合の遊佐勝，川村秀次郎，安保保太郎等の各位に御世話になり，又養魚については，本学部久保達郎助教授の労を煩わしたところが多い。又写真は同助教授考案作製の投影器によつたもので，玆に記して各位に深謝の意を表する。

II 実験の方法

北海道亀田郡に在る大沼には前記の様に琵琶湖産源五郎鮒が移殖され，よく成育繁殖して，毎年5月中頃其の産卵期には湖岸に於て筌による漁獲が多く，成熟した親魚を得て，容易に其の人工受精卵をつくることが出来る。本研究は此の卵より孵化した稚魚を飼育して研究の材料としたもので，飼育は当学部所属の七飯養魚場（函館市外七飯村）の養魚池又は水田に於て行い，当才の秋末には之を同所の冬囲池に移して越冬せしめた(此の間給餌せず，用水は川水を引用す)。而して第2年目の春には之を冬囲池より養魚池又は水田に移して2才の秋まで飼育した。尚此の飼育実験は次記の如く3回くり返し実施した。

第1回　昭和23年5月採卵，翌24年8月に至るもので，二夏飼育，此の間1回越冬のもの。
第2回　昭和24年5月採卵，翌25年11月に至るもので，二夏飼育，此の間1回越冬のもの。
第3回　昭和25年6月採卵，翌26年11月に至るもので，二夏飼育，此の間1回越冬のもの。

上記3回の飼育実験に於て，各回とも夫々，当才の秋，翌春，2才の秋の3時期の標本を採取し，10%フォルマリン液に固定保存して研究の材料とした。各期採取の尾数は一定しなかつたが，略大，中，小魚を網羅して居る。

鱗相の観察は採取した研究材料の各尾につき，其の魚体の側線の上位に於て，体の前・中・後の3部位から採取した鱗を以て行うた。

III 実験の結果

鮒の鱗[9]は円鱗で，其の形状は体の部位により変化があるが，大体角のまるい不規則な五角形乃至六角形に近いものが多い。普通の鱗の様に前部即ち被覆部と，後部即ち露出部と明に区別があり，focus は鱗の中央よりも稍後方に位置するものが多い。被覆部に見られる circuli は密に相接近して focus を中心として環状に並んで鱗の周縁に及んで居る。此の被覆部の circuli の多くは，露出部との境界附近にて終り，露出部にまで延びるものが少なくなる為に，此の部の circuli は被覆部に比して甚だ疎となつて居る。circuli は多少波状になつて走る弧線で，途中分岐するものもあり又途中で切れてしまうものもある。radii は其の数少なく至つて疎であるが，被覆部にも露出部にも共に顕著に出現して居る。

Cockerell[10]は淡水魚鱗の研究に於て circuli の外に real line of growth のあることを指摘して居るが，

小林[9]も此の成長線（growth line）のあることを説き，鯉科魚類の各種につき此の成長線の有無及び其の性状の相違を述べて居る。而して特に鯉鱗には其の露出部に明に之が認められ，鮒鱗には之を欠くとし，両種の著しい相違として居る。然るに筆者の見るところでは，大沼産の源五郎鮒にも，従来の普通の鮒にも，其の鱗にcirculi以外に，小林の所謂成長線に相当すると思われる細線が見られる。此の成長線はfocusを中心として環状に走るやゝ透明な細線で，其の数は少ないが，露出部に於てはcirculiが疎であるので容易に之を認めることが出来る。被覆部ではcirculiが密である為に，認めにくいものもあるが，注意すれば此所にも見出される。但し鯉鱗と比較すれば，鮒鱗の成長線の方がやゝ著明でない。

尚幾年かを経過した鮒の鱗には其の被覆部に幾本かの所謂annuli（年輪）が見られる。而して此の中には年輪類似の輪線即ち所謂false annuli（偽年輪）が混在することも考えられる。

此の所謂年輪及び偽年輪の性状については後に記述する。

3回の飼育実験の大要を一括して示せば次の様である。

実験	研究材料固定時	同尾数	同体長 最大	同体長 最小	同体長 全平均	鱗相
	年月日		mm	mm	mm	
第1回（昭和23年5月18日採卵）	当才秋(23.10.23)	8	78	54	65.5	偽年輪を有する個体がある
	翌春(24. 5.12)	5	75	55	64.6	同上
	同 (24. 7. 4)	10	74	48	59.4	同上
	2才秋(24. 8.26)	9	106	89	95.4	第1年目の成長の部分に偽年輪を有する個体がある 第1年目と第2年目の成長の間に明瞭な一条の所謂年輪が形成されて居る
第2回（昭和24年5月18日採卵）	当才秋(24.10.21)	25	66	35	48.6	年輪類似のものが形成されてない
	翌春(25. 6. 6)	15	55	41	47.1	同上
	2才秋 水田 (25. 9. 9)	10	84	64	74.3	第1年目と第2年目の成長の間に明瞭な一条の所謂年輪が形成されて居る
	〃 養魚池 (25.11.10)	10	102	77	88.4	同上
第3回（昭和25年6月7日採卵）	当才秋(25.11.10)	10	72	58	65.5	偽年輪を有する個体がある
	翌春(26. 7.11)	11	90	53	70.0	同上
	2才秋(26.11. 1)	6	114	85	102.3	第1年目の成長の部分に偽年輪を有する個体がある 第1年目と第2年目の成長の間に明瞭な一条の所謂年輪が形成されて居る

説明の都合上**第2回の実験**結果から述べることにする。

昭和24年5月18日大沼に於て採卵し，当学部構内コンクリート池にて孵化したものを，6月7日に七飯養魚場の養魚池に放養して，一夏飼育し其の秋10月21日取揚げたものから研究材料として大小25尾を採取した。

此の材料の鱗相を検するにFig. 1の様で，circuliの並び具合に特別な変化のある部分がなく，所謂年輪類似のものは見られない。しかも又同一魚体の前・中・後部の鱗に於て相違することがないばかりでなく，検査材料25尾に於て皆同様で，1尾の例外もなかつた。

次に此の秋に取揚げた魚を冬囲池に移して越冬せしめ，翌25年6月6日之を取揚げ，15尾の標本につき其の鱗相を観察するに，前年秋の冬囲池移入当時と異なるところがなく，15尾の材料全部同様であつた。

此の6月6日に冬囲池より取揚げの所謂明2才魚を，一部は水田に単養，一部は明2才の鯉と養魚池に混

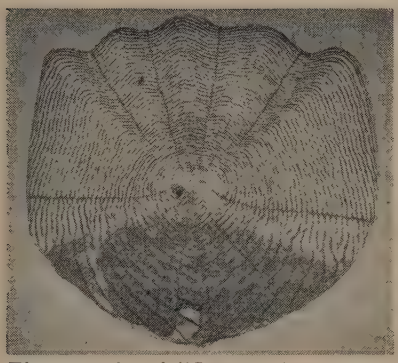

Fig. 1. Scale of "Gengoro-buna" at end of first autumn
Date of spawn taking…… May 18, 1949
Date of capture…… October 21, 1949
Body length of fish……66mm

次に記述が前後したが，**第1回の実験**は昭和23年5月18日大沼に於て採卵し，当学部構内にて孵化したものを，5月31日に，七飯養魚場の水田の一角に造つた小池に入れて置いたのであるが，之が何時か其の下流に在る鯉の養魚池に下つて此所に混入し其の年の10月23日，此の池の鯉の取揚げの時に95尾を発見採集した。此の日8尾を研究材料として固定し，残りは之を冬囲池に移して越冬せしめた。而して其の後翌春5月12日に取揚げ固定せるものと，更に其の後7月4日まで冬囲池に留めて取揚げ固定せるものと，同日之を養魚池に移して鯉と混養飼育し，8月26日に取揚げ固定せるものとがある。斯くて此の飼育実験に於ても第1回と同様，当才の秋，翌春及び2才の秋の3時期の魚の鱗の紋様を観察することが出来た。

養して一夏飼育し，前者は9月9日，後者は11月10日に取揚げ，夫々10尾の研究材料につき観察したところ次の様である。

即ち此の魚は生後2年目の秋の2才魚であるが，其の鱗の被覆部に普通所謂年輪と称せられる明瞭な一輪紋を成す部分が認められた(Fig. 2)。而して此の輪紋の位置は，鱗の成長の具合から見て，第1年目と第2年目の成長の間に介在して居り，且つ何れの標本に於ても皆1本のみであつた。且つ又第1年目及び第2年目の部分に偽年輪を認めなかつた。

此れ等の事実は，水田飼育のものも，養魚池飼育のものも1尾の例外もなく一致して居つた。

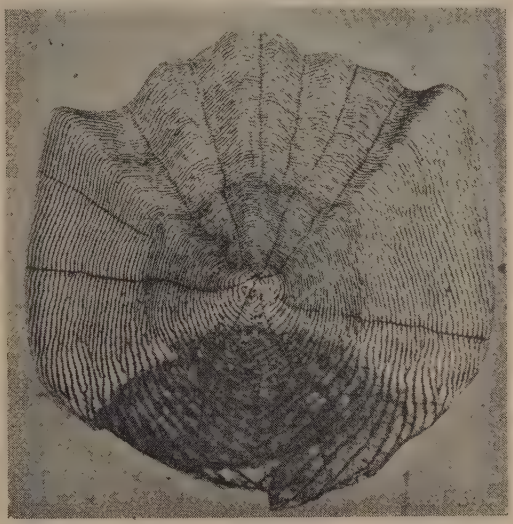

Fig. 2. Scale of "Gengoro-buna" at end of second autumn
Date of spawn taking……May 18, 1949
Date of capture ……November 10, 1950
Body length of fish……84mm

先づ当才の秋の魚の鱗には，前記第2回の飼育実験の魚と異なり，研究材料8尾の中に年輪類似のものの出現して居るものが6尾あつた。但し此の6尾中5尾の鱗は其の輪紋がやや不明瞭又は不完全で，年輪認定の際にやゝ疑問をいだかしめる程度のものであるが，他の1尾に於ては所謂年輪と誤認される程に明瞭に現われて居つた(Fig. 3)。然し之は確実に第1年の夏の間に不規則に出現したもので，云うまでもなく偽年輪である。

尚又越冬せしめて翌年5月12日に取揚げ固定したもの，及び7月4日に固定したものに於ても，前年即ち当才中に偽年輪の出現した鱗を持つものが二者の研究材料合計15尾の中，8尾あり，就中4尾の如きは甚だ顕著なものであつた。

Fig. 3. Scale of "Gengoro-buna" at end of first autumn, which has a distinct false annulus

次に2才の秋の魚の鱗に於ては，前記第2回の実験材料と同様に，第1年目と第2年目との間に，1尾の例外もなく，明瞭な1本の所謂年輪が形成されて居つた。而して第2年目の成長に属する部分には偽年輪は1尾にも見られなかつた。

第3回の実験は昭和25年6月大沼に於て採卵，之を当学部構内にて孵化し，7月10日七飯養魚場に移して，当才の鯉稚魚と混養したもので，同年11月10日に之を取揚げ（此の時の固定材料10尾），同場内孵化室の水槽中に越冬せしめた。而して翌26年7月11日之を養魚池に移し（此の時の固定材料11尾），明2才の鯉と混養飼育して，其の11月1日に取揚げた（此の時の固定材料6尾）。

此の実験に於ても上記3時期の研究材料があり，此の各時期の魚の鱗相を観察するに次の様である。

先づ当才秋の魚に於ては，此の年のものにも，第1回の実験材料の様に偽年輪が出来て居つた。即ち研究材料10尾中6尾の鱗に之を見出し，就中1尾の如きは非常に明瞭にして真の年輪と誤認される程であつた。尚又越年して翌年7月11日に固定のものに於ても，鱗の第1年目の成長に属する部分に偽年輪を持つものがあり，研究材料11尾中9尾に之が見出された。此の中4尾は甚だ明瞭なものであつた。

2才の秋の魚の鱗に於ては，第1回，第2回の実験材料と同様に，1尾の例外もなく，第1年目と第2年目との間に明瞭な1本の所謂年輪が出現して居り，又第2年目に属する部分には偽年輪を見出さなかつた。

Ⅳ 年輪の観察

前記3回の実験に於ける2才の秋の魚の鱗には，第1年目と第2年目の成長の間に，必ず1本の所謂年輪が出現するが（以下暫く之を年輪と仮称する），此処に此の輪紋の部分について観察して見よう。

先ず此の年輪は，此所に特別な一線がある訳でなく，circuliの出来具合或は其の連繋が，此の部分に於て少しく不規則或は他の部分と少々異なる為に，顕微鏡の拡大を低くして見る時には，此の部分が相つらなつて恰も特別な一輪線を成す様になる。而して此のcirculiの具合の不規則或は変調になる状態は，年輪の前の部分と，左右即ち背・腹の部分に於て多少其の趣を異にするもので，次に年輪を此の両部に分けて其の状態を述べることにする。

1. 年輪の前の部分

　此の部分の年輪の構成様式は略一式で，凡そ次の様である。即ち相接する2，3本の circuli の間隔が他の部分よりもやや狭くなるばかりでなくcirculi の具合が多少不規則となる部分等も出来，之が年輪を構成する（Fig. 4）。

2. 年輪の背・腹の部分

　此の部分の年輪の構成様式は一様でなく其の代表的なものを挙げて見ると，少なくも次の三つの型がある様である。

　A型　当才の秋の鮒について見るに，

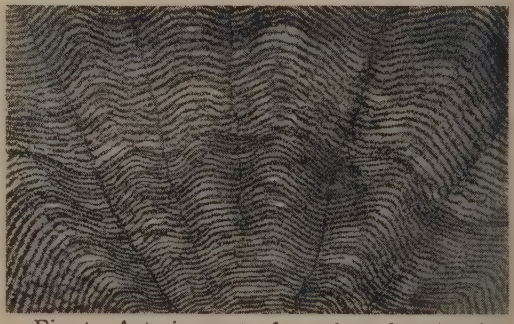

Fig. 4. Anterior part of annulus of scale of "Gengoro-buna"
Note construction of annulus

circuliの中，鱗の周縁に近いものは，其の両端が鱗の被覆部と露出部との境まで達せず，途中で順次に鱗の周縁に終つて居る。而して其の翌年に出来るcirculiは，此の前年のcirculiと関係なく，鱗の周縁に添うて新生される型のもので，此所に判然たる境界線が見られる事になる(Fig. 5)。

B型　第2年目にcirculiが新生される時に，A型と異なり，前年鱗の周縁で終つて居るcirculiが連続して延びて行くものと考えられるもので，此の場合其の相接する2,3本のcirculiの間隔が他よりもやや狭くなるので，之が年輪を構成する(Fig. 6)。

C型　B型と同じくcirculiは新生に当つて前年のものが連続して延びて行くが，之が所謂年輪の部分を横切つて其の外側に走り出て居る。但し年輪に当る部分で，相隣接するcirculiが狭く相近接するため，此の部分が相つらなつて年輪を成す様になる(Fig. 7)。

Fig. 5. Lateral part of annulus of scale of "Gengoro-buna," Type A

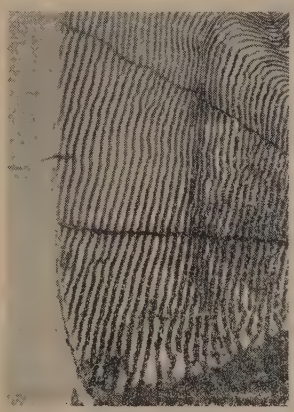

Fig. 6. Lateral part of annulus of scale of "Gengoro-buna," Type B

Fig. 7. Lateral part of annulus of scale of "Gengoro-buna," Type C

一般に年輪の前の部分は，前述の様に其の構成様式が簡単で，しかも年輪が明瞭であるが，背・腹の部分は其の構成様式が多様である。上記には其の代表的のものを挙げたのであるが，此の外に一部分A型で一部分B型，或は一部分B型で一部分C型等もあり，更に又不規則のものも認められる。而して背・腹やや同様式即ち相称的なものもあるが，背・腹一致しないものもある。又此の年輪の背・腹部に当るところは其の構成の具合によつて甚だ明瞭のものもあるが(例へばA型の如く)，年輪の前の部分に比して一般にやや判明を欠き，個体によつては甚だ判然しないものもある。

尚上記A型の年輪は鮒の鱗ばかりでなく，色々の魚に見られるもので，安田[5]の当年のアユの鱗に顕われた輪紋の研究で同氏がA型としたものも之である。又Lagler[11]やRounsefell & Everhart[12]等がcutting over或はcrossing over等と云うて居るのが此の型で，年輪を識別する最も良い性質の一つとして居る。

鮒の鱗にcirculiの外に成長線の認められることは先に述べた如くであるが，此の成長線が年輪の部分に認められるものは，其の年輪が一層明瞭になる様である。

偽年輪は年輪類似の輪紋で，前記第1回及び第3回の飼育実験に於て，其の第1年目に或る個体の鱗に出現した。其の良く発達したものは上記の年輪と区別が困難な程で(Fig. 3)，此の場合偽年輪の構成状態をよく観察するに，其の前部並に背・腹部に於ても年輪と殆んど区別すべき点がない。然し偽年輪の多くは其の輪紋が年輪に比して明瞭を欠き，或は不完全である。之は云うまでもなく其の輪紋の構成が不充分であり，或は輪紋が一部分のみに現われて居る為である。

V 考 察

此処に考察の便宜上，本飼育実験結果の要点を挙げて見ると次の様である。

項目	昭和24年孵化の材料	昭和23年及び25年孵化の材料
第1項 第1年目に偽年輪出現の有無	全然出現しない	偽年輪の出現した個体もあり，其の中には年輪と誤認される程に明瞭な輪紋をなすものもある
第2項 第2年目の秋には第1年目と第2年目の成長の間に一条の明瞭な所謂年輪が出現して居る	左記の通り	左記の通り
第3項 第2年目の成長に属する部分には偽年輪は出現しない	左記の通り	左記の通り

上記3回の実験中，昭和24年採卵，飼育の実験結果は，常識的に一般に予期さるゝものであり，しかも採取した研究材料中1尾の例外もなく，同様に揃つた結果が出て居つたのであるが，昭和23年及び25年に採卵飼育のものに於ては，上記実験結果の第1項が24年のものと異なり，第1年目に或る個体に偽年輪が出現した。然し第2及び第3項に於ては，3回の実験共よく一致した結果が出て居る。

先づ**第2項**の第2年目秋の魚の鱗面（Fig. 2）に於て所謂年輪の内側及び外側の部分は夫々第1年目及び第2年目の魚の成長期即ち主として夫々の夏の間に出来た部分であることは云うまでもなく，所謂 summer zone（夏帯）と呼ばれる部分であり，其の間に介在する輪紋は所謂冬輪に相当する処である。而して之をこれまで便宜上仮に年輪と呼んで来たが，3回に及ぶ此の飼育実験に於て，例外なく夏帯と夏帯との間に此の明瞭な一輪紋の出現を見た事は，源五郎鮒に於て此の輪紋が真の年輪であることを事実に示したものと認めてよいと思う。只茲に2年以上の飼育実験を欠き遺憾とする。又本実験は天然と其の趣の異なる養魚池，冬囲池等に於て行うたものであるが，鮒の鱗の年輪の成生に最も大きな影響があると思われる水温の変化に於ては天然の湖沼と相似たものであるから，天然のものも同様であると考えて差支へないと思う。

年輪は普通冬期間に形成される所謂 winter ring（冬輪）を指して居るが，此の年輪の出現する時期は魚の種類によつて異なる様である。Van Oosten[13]（直接引用出来ず[14]による）は white fish を水槽に飼育実験し，年輪は鱗の成長の盛んになる4,5月頃に完成されるとし，天然に於ても恐らくそうであると考えることが安全と思うと云うて居る。雨宮・桧山[14]は公魚について季節的に変化する鱗面の circuli の状態から，狭帯即ち冬帯の出来るのは，9月から2月の間であるとして居る。中村[15]は千曲川のオイカワでは冬輪の形成されるのは普通9月頃からで，翌年5月中，下旬頃から夏輪に移ると云うて居る。此れ等に於ては何れも冬輪の出来るのは主として冬期間で，完成は春に及ぶ様である。然るに Dannevig[16]は南部ノールウェーの trout の鱗に出現する circuli の密な部分は，必ずしも冬期間と限らず，地方によつて夏や晩夏乃至は秋等に作られると報告し，少なくも此の地方の trout では winter zone と云う名称は妥当でないと云うて居る。

海の魚では淡水魚と多少変つて来ることも考えられるが，Culter[17]は plaice や flounder で実験し，summer band は夏に，winter band は冬に出来ることを確かめて居る。海老名[18]は真鯛の鱗を調査し12月～3月の間は鱗の成長が休止し，冬輪の確実に認められるのは3月上旬になつてからだと云うて居る。そうすると真鯛では春鱗の成長が始まつてはじめて冬輪が認められる様になると思われる。宮崎[19]はマハゼの鱗相を観察し circuli の間隔の広い処は10月～4月，狭い処は5月～10月の間に形成される事を見，一般に考えられるところと反対で，Dannevig の研究したノールウェーの *Gadus* と似て居ると報じて居る。

本研究に於ては，年輪形成の時期に関する実験を欠き，之に就いては今後の研究に待たねばならないが，今現在ある材料により之を一考して見るならば凡そ次の様な事が解る。即ち当才並びに2才の秋の魚の鱗の周縁を観察するに，其処には年輪形成の徴候は認められない。更に此の当才魚を冬囲池に越冬せしめ，翌春5月に，更に又之を其のまま冬囲池に置いて7月に至つたものについて検するに，皆同様に年輪の出来始め

て居る模様がない。此の様に秋から冬を越し，翌春まだ冬囲池に在つて成長を始めない間は，年輪の形成が始まらないものの様である。本飼育実験に於ては冬囲池より養魚池に移入後其の秋まで中間標本を採取しなかつたので，年輪の出来始めを確め得ないが，2才の秋の標本により其の年輪構成の状態から考察して見ると，源五郎鮒の鱗の年輪は春，魚が成長を始むる時に新生されるcirculiによつて其処に出現して来るものの様に思われる。前記年輪の構成の処に述べた年輪の背・腹部のA型に於て殊に此の考えが裏づけされる様に思う。Lagler[11]及びRounsefell & Everhart[12]も春，魚の成長が始まる時に，所謂cutting over或はcutting acrossか起ると述べて居る。又上記海老名[18]の真鯛の冬輪の形成が筆者の想像の如くであれば，真鯛に於ても春，魚の成長の始めに冬輪が形成されることになる訳である。

第3項即ち第2年目の夏帯に偽年輪が出現しなかつた事は，3回の実験に於て一致して居るとは云え，第1年目の夏帯に之が出来ることがあるに拘らず，第2年目に全然之が出現しなかつた事は，偶然の一致とも考えられるし，又少なくも第2年目には偽年輪が出来にくくなると云う様な事にも考えられるが，之は今後に残る問題とする。

第1項の第1年目の夏帯に或る個体には偽年輪が出来，しかも之が真の年輪と誤認される程度に判然たるものかあつたと云うことは，年輪と相対して充分な検討を要することである。本実験に於ては，此の偽年輪成生に関する実験を行わなかつたので，いかなる時に之が出現するかは今後の実験に待たねばならないが虹鱒[20]については食餌の給与の多少がcirculiの成生に疎密をきたすことが報告されて居り，鮎の鱗に見られる輪紋は安田[5]は食餌の変化とし，堀井[6]は環境の変化によるとして居る。又貝類の貝殻面にも冬輪の外に之に類似の輪線の出来ることがあるが，山本[21]は樺太産北寄貝にて研究し，天然の棲息地に於ける時期的な水温の降下が其の成因であると報じて居る。鮒に於ても恐らく飼育場所の移動や食餌，水温等色々な環境の変化によつて，偽年輪の出来る場合のあることは想像に難くない。

此の偽年輪は上記鮎の如く，天然産のものにも各種の魚に於て認められるところで，Van Oosten[4]はヒューロン湖のLake herringの鱗につき真の年輪と区別のつかぬ様なもののあることを報じて居るが，天然産の鮒に於ても之あることを考えねばならない。然りとすれば鱗による年齢の査定が不確実となつて来る。然らば実際問題としてどうすればよいかと云うことになるが，之には偽年輪に関し次の様な事が考えられる。[12][22][23]

1. 偽年輪は真の年輪に比し多くは明瞭でなく，又不完全である。
2. 然し真の年輪と識別困難な程によく発達したものもある。
3. 従つて此の偽年輪により魚齢を実際よりも多く査定することも起り得る訳であるが，魚の成長度と比較吟味すれば，大抵年齢に疑問が起る。
4. 偽年輪が出来て居る場合には，年輪間（偽年輪も含めて）の間隔が比較的狭くなる訳であるから，此の点も注意すべき事である。

以上は偽年輪を区別し発見するに役立つ注意事項であると思う。

VI　要　　約

本実験の全般につき之を要約すれば次の様である。

1. 源五郎鮒を飼育し，其の鱗相特に輪紋の成生について観察した。
2. 鱗の夏帯と夏帯との間に必ず一条の明瞭な冬輪が出現する。
3. 本飼育実験の結果から，此の冬輪は真の年輪として年齢査定の準拠としてよいと思う。
4. 年輪のcirculiによる構成様式は，年輪の前部と背・腹部とにて異なり，前部は簡単に一式であるが，背・腹部は色々な型がある。其の代表的なものとしてA，B及びCの3型を挙げた。
5. 年輪の出来る時期は春，鱗の成長の始まる時の様に思われる。
6. 個体により偽年輪の出来ることもある。

7. 偽年輪は多くは多少明瞭度を欠き又は不完全であるが，中には真の年輪と識別困難な程によく形成されたものもある。
8. 偽年輪の識別の事も考えて見た。

引 用 文 献

1) 藤田経信 (1932). 水産学通論. 東京.
2) Hoffbauer, C. (1898). Die Altersbestimmung des Karpfens an seiner Schuppe. *Allgem. Fischerei-Ztg.* **23** (19).
3) 相川広秋 (1949). 水産資源学総論. 東京.
4) Van Oosten, J. (1928). Life history of the lake herring (*Leucichthys artedi* LE SUEUR) of Lake Huron as revealed by its scales, with a critique of the scale method. *Bull. U. S. Bur. Fish.* **44** (Doc. No. 1053).
5) 安田秀明 (1941). 当年アユの鱗に顕はれた2つの輪紋に就ての考察. 日水誌 **9** (5).
6) 堀井正雄 (1952). 成育環況を異にする同種諸アユの鱗の形態. 魚雑 **2** (2).
7) Jordan, D. S. & Hubbs, C. L. (The Salmonidae by D. S. Jordan and E. A. McGregor) (1925). Record of fishes obtained by David Starr Jordan in Japan, 1922. *Mem. Carnegie Mus.* **10** (2).
8) 松井佳一 (1950). 日本産コイ・フナ及びその雑種について. 中村健児編現代生物学の諸問題. (152～188). 東京.
9) 小林久雄 (1937～1938). 日本産鯉科魚類鱗相の比較研究 1～5. 植物及動物 **5**(10), (11), (12); **6** (7), (9).
10) Cockerell, T. D. A. (1911). The scales of freshwater fishes. *Biol. Bull.* **20** (6).
11) Lagler, K. F. (1952). *Freshwater fishery biology*. Dubuque, Iowa.
12) Rounsefell, G. A. & Everhart, W. H. (1953). *Fishery science*. New York.
13) Van Oosten (1932). The whitefishes (*Coregonus clupeaformis*). A study of the scales of whitefishes of known ages. *Zoologica* **2** (17).
14) 雨宮育作・桧山義夫 (1940). 公魚の産卵及び年齢に就きて. 水産学会報 **8** (1).
15) 中村一雄 (1952). 千曲川産オイカワの生活史並に其の漁業. 淡水区水研報 **1** (1).
16) Dannevig, K. & Dannevig, G. (1937). The season in which "winter" zones in the scales of trout from southern Norway are formed. *Journ. du Cons.* **12** (2).
17) Culter, D. W. (1918). A preliminary account of the production of annual rings in the scales of plaice and flounders. *Journ. Mar. Biol. Assoc.* **11** (4).
18) 海老名謙一 (1940). 真鯛群の系統的研究 III. 日水誌 **8** (6).
19) 宮崎一老 (1940). マハゼに就て. 同誌 **9** (4).
20) Bhatia, D. (1931). On the production of annual zones in the scales of the rainbow trout (*Salmo irideus*). *Journ. Exp. Zool.* **59** (1).
21) 山本喜一郎 (1947). 北寄貝の貝殻の成長に就て. 札幌農林学会報 **37** (2).
22) Lee, R. M. (1920). A review of the methods of age and growth determination in fishes by means of scales. *Minist. Agr. Fish., Fish. Invest.* Ser. II. **4** (2).
23) Hile, R. (1935). Age and growth of the cisco, *Leucichthys artedi* (LE SUEUR), in the lakes of the northeastern highlands, Wisconsin. *Bull. U. S. Bur. Fish.* **48** (19).

北海道海区に於ける鯖巾着網漁業の研究

第3報　綿漁網とクレモナ漁網との混合鯖巾着網の構成上の一考察

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Studies on the Fishery of Mackerel by Purse Seines in the Sea near Hokkaido

3. A study on the mackerel purse seines which are composed of cotton nets and cremona nets

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Abstract

Purse seines which are composed of cotton nets and cremona nets have come into wide use during the fishing season. Since their tensile strength and durability are greater than those of cotton net, such seines seem to be effectively used for the large scale roundhaul nets, especially for the purse seines, from the view point of the composition of the fishing gear and of the particular method of fishing.

But it remains to be learned why the knots of cremona net are weak and why the cotton nets are now used for the bag nets of the purse seines.

1　緒　　言

現今沿岸及び沖合漁業に於いて，広く合成繊維漁網の使用が叫ばれており，特に鰯，鯵，鰤，鮪及び鰤の旋網類には，昭和27年以降試験使用されるに至つた。中でも国産合成繊維のクレモナ漁網（クレモナ漁網用原糸：パーロック式ビニロン紡績糸）は，多方面に其の利用度が高く，本道海区での操業時の鯖巾着網でも其の網の一部に此のクレモナ漁網を使用し始めたものもある。即ち台網の本網及び同局部の浮子方，沈子方，縁網には綿漁網（15～21本×5～7節）を使用し[1,2]，其の他の局部，即ち台脇，胴，臀網の本網及び縁網には，クレモナ漁網（無結節8～14本×5～7節）を使用している。

著者等は之等最近使用されるに至つた綿網とクレモナ漁網との混合巾着網の構成上の一考察として，現在鯖巾着網の各局部を構成している綿網の同太，同号数のクレモナ漁網との張力試験を行い，此処に報告すると共に，此の混合鯖巾着網の方が，従来，使用されて来た綿網巾着網より，其の構成上より見た使用中に於ける抗張力の点，其の他操業上の点で，極めて有効であることを認め，併せて報告する。

2　材料及び試験方法

試験材料は綿糸20番手，左撚5号及び6号（日本漁網株式会社）とクレモナ漁網糸，左撚$^{20}/_{15}$，及び$^{20}/_{18}$（倉敷レイヨン株式会社）を第1表で示した如く各々24種類の網地に10本づつ手編きにし約20時間浸水せるものを使用した。

尚，試験方法は，前試験方法と全く同様に行つた。（本試験方法は，巾着網の構成上の点からは，勿論，漁法上から見て，本網に働く張力は，浮子方及び沈子方の方向，即ち横向きの方向に働く張力が最大なものとして行つた。）

3 試 験 結 果

以上の試験材料及び試験方法に従い，即ち5号，6号の綿網と$^{20}/_{15}$，$^{20}/_{18}$のクレモナ漁網との張力試験を行つた。第1図は，綿網及びクレモナ漁網の太さ，目合の別から見た全試験材料の張力試験結果であり，第2図は，之等網地の伸びの結果である。又，第3図（1～4）は，之等の試験結果を結節及び網地の使用方向別に見た張力試験結果である。即ち全般的に見て，

1. 張力の最も強いのは，綿網6号，2寸5分目の本目及び蛙股結節の網地を縦下しの方向に引いた時であり，最も弱いのは，クレモナ漁網$^{20}/_{15}$を目合の別なく，本目及び蛙股結節（特に蛙股結節）の網地を巾の方向に引いた時である。

2. 試験結果では，綿網の張力が，クレモナ漁網の張力より稍強く，且之等の同一条件での張力を見る時5号より6号の方が，又，$^{20}/_{15}$より$^{20}/_{18}$の方が強い。

3. 一般に綿網の場合は，本目及び蛙股結節の網地とも割合縦下しの方向に引く時の張力は強く，逆に巾の方向に引く時の張力は，同一の目合及び太さのものに於いては，蛙股結節の網地の方が本目の網地より強い。

4. 一方クレモナ漁網の場合も，縦下しの方向に引く時の張力は，綿網の場合と同じ事が云えるが，巾の方向に引く時の張力は，逆に本目結節の網地の方が，蛙股の網地より強い。

5. 結節に無関係に，同一の目合，太さの綿網の縦下しの方向に引く時の張力を之等と同一の目合，及び太さの巾の方向に引く時の張力と比較するに，6号の1寸5分目の網地で約17%，2寸目で14%，2寸5分目で18%，又5号の1寸5分の網地で約7%，2寸目で3%，2寸5分目で12%それぞれ強く，一方クレモナ漁網では，此れと同一条件で縦下しの方向に引く時の張力を，巾の方向に引く時の張力と比較するに，$^{20}/_{18}$の1寸5分目の網地で約26%，2寸目で24%，2寸5分目で23%，又$^{20}/_{15}$の1寸5分目の網地で約28%，2寸目で27%，2寸5分目で23%それぞれ強く，一般にクレモナ漁網では，$^{20}/_{18}$，$^{20}/_{15}$ともに，縦下しと巾の方向に引く時との張力の差が大きく，此の点綿網は，5号，6号とも，其の差小さく，特に試験結果より5号の場合は，其の差が僅少であつた。

6. 綿網及びクレモナ漁網の伸びに就いて見るに，同一の太さ，目合のもとに，本目及び蛙股結節の網地を縦下し又は巾の何れの方向に引いても，綿網，クレモナ漁網とも大差が見られない。

4 考 察

試験当初の綿網の張力は，クレモナ漁網のそれより-も強いが，然し著者等は先に之等に関連した各種綿網染料の効力試験及び各種綿網の張力試験結果より見て，本道両海区の鮪漁期（6月中旬～9月初旬）に使用する巾着網の各局部の網地（台の部：C.20′S. NO. 6，台脇の部：C.20′S. NO. 5，胴及び臀部：C.20′S. NO.5～4）の染料には，殆んどコールタールを用い，之等染料を使用した綿漁網が本道両海区の漁期中での張力の減少率は，約20～25%と見られ，一方，クレモナ漁網に於いては，各処に於ける各種旋網類及び定置網の張力試験結果[3]を見ても，又本道海区の鮪漁期の使用時に於いても，網地自体の疲労，消耗，即ち抗張力の減少が殆んどなく，此の点から見ても混合巾着網は，綿網より有効であり，即ち5～6号の綿網の使用中に起る抗張力の減退を考える時，現在混合巾着網の台脇，胴及び臀部に使用しているクレモナ漁網には，本試験で使用した$^{20}/_{15}$，$^{20}/_{18}$の如き太目の網地は不要であり，即ち綿網巾着網の場合の同局部の網地より細目の網地を使用しても，此のクレモナ漁網の張力が，綿網の漁期中の使用限界張力以上であれば，支障がないものと思われる（本目結節で横目に使用す）。

尚，綿網の鮪巾着網では，一般に春漁期（対馬，堺，若狭湾海区）及び晩春から夏漁期（石川，北海道海区）に使用した際は，次期操業（島根，山口，対馬海区）には約50%網地の補給をせねばならず，之等資材の補給状況から見ても不朽性強く，又操業上から見ても綿網より軽く，且漁期中に於いては綿網と異り，網

干も余り必要とせず，之等労力の点から見てもクレモナ漁網は綿網よりは有効，且有利である。

5 結　　言

最近，使用されるに至つた混合巾着網は，其の漁期中に於ける抗張力及び不朽性は，綿網より強く，漁具の構成上から見ても，又特殊漁法の点から見ても大規模な旋網，特に巾着網には有効と認める。

尚，クレモナ漁網の結節の点及び混合巾着網の台網部には，従来の綿網を使用しており，これが原因は今後の研究に俟たねばならぬ。

文　　献

1) 川崎・西山・中村（1953）．北大水産彙報 3 (4)．
2) ――――――（1953）．同誌 5 (1)．
3) 三重県水試尾鷲分場（1954）．定置網に対する合成繊維の適否試験報告 (3)．

Table 1. Tension tests of the various nets (m : meshes)

Cotton nets						
Sign of test net	Material and number	Size of mesh	Number of mesh	Knot	Length of net	Number of material
A	C20'SNo.5	1.5 sun	4 m	F.K*	8 m	10
B	No.6	〃	〃	〃	〃	〃
C	No.5	〃	〃	T.K	〃	〃
D	No.6	〃	〃	〃	〃	〃
E	No.5	1.5 sun	8 m	F.K	4 m	10
F	No.6	〃	〃	〃	〃	〃
G	No.5	〃	〃	T.K	〃	〃
H	No.6	〃	〃	〃	〃	〃
I	No.5	2.0 sun	4 m	F.K	8 m	10
J	No.6	〃	〃	〃	〃	〃
K	No.5	〃	〃	T.K	〃	〃
L	No.6	〃	〃	〃	〃	〃
M	No.5	2.0 sun	8 m	F.K	4 m	10
N	No.6	〃	〃	〃	〃	〃
O	No.5	〃	〃	T.K	〃	〃
P	No.6	〃	〃	〃	〃	〃
Q	No.5	2.5 sun	4 m	F.K	8 m	10
R	No.6	〃	〃	〃	〃	〃
S	No.5	〃	〃	T.K	〃	〃
T	No.6	〃	〃	〃	〃	〃
U	No.5	2.5 sun	8 m	F.K	4 m	10
V	No.6	〃	〃	〃	〃	〃
W	No.5	〃	〃	T.K	〃	〃
X	No.6	〃	〃	〃	〃	〃

* F.K : Flat knot, T.K : Trawler's knot

Cremona nets						
Sign of test net	Material and number	Size of mesh	Number of mesh	Knot	Length of net	Number of material
a	20/15	1.5 sun	4 m	F.K	8 m	10
b	20/18	〃	〃	〃	〃	〃
c	20/15	〃	〃	T.K	〃	〃
d	20/18	〃	〃	〃	〃	〃
e	20/15	1.5 sun	8 m	F.K	4 m	10
f	20/18	〃	〃	〃	〃	〃
g	20/15	〃	〃	T.K	〃	〃
h	20/18	〃	〃	〃	〃	〃
i	20/15	2.0 sun	4 m	F.K	8 m	10
j	20/18	〃	〃	〃	〃	〃
k	20/15	〃	〃	T.K	〃	〃
l	20/18	〃	〃	〃	〃	〃
m	20/15	2.0 sun	8 m	F.K	4 m	10
n	20/18	〃	〃	〃	〃	〃
o	20/15	〃	〃	T.K	〃	〃
p	20/18	〃	〃	〃	〃	〃
q	20/15	2.5 sun	4 m	F.K	8 m	10
r	20/18	〃	〃	〃	〃	〃
s	20/15	〃	〃	T.K	〃	〃
t	20/18	〃	〃	〃	〃	〃
u	20/15	2.5 sun	8 m	F.K	4 m	10
v	20/18	〃	〃	〃	〃	〃
w	20/15	〃	〃	T.K	〃	〃
x	20/18	〃	〃	〃	〃	〃

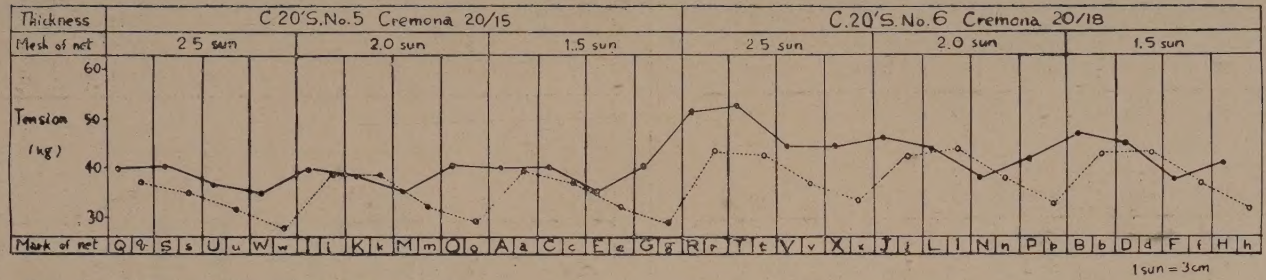

Fig. 1. The results of tension test ●—● : Cotton ○···○ : Cremona

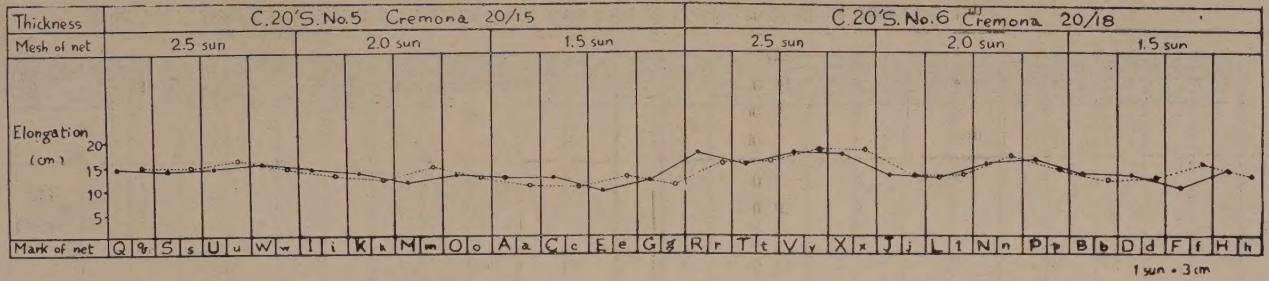

Fig. 2. The results of elongation test ●—● : Cotton ○···○ : Cremona

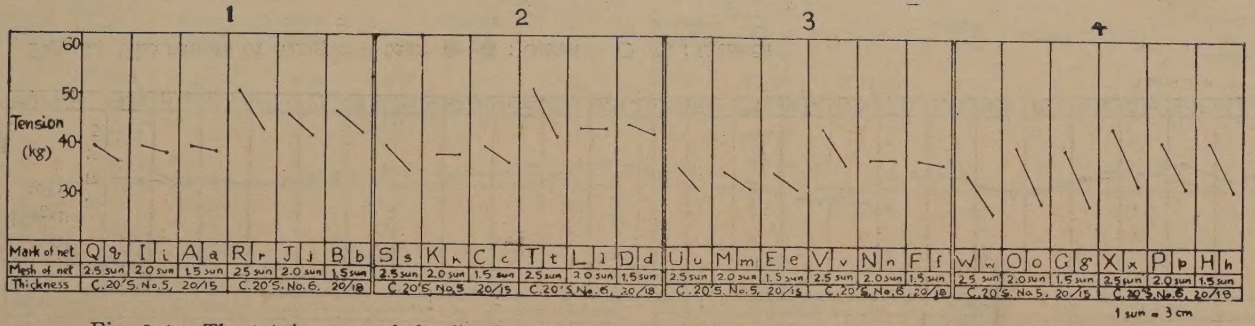

Fig. 3-1. The tension test of the flat-knot nets torn in their longitudinal direction

Fig. 3-2. The tension test of the trawler's-knot nets torn in their longitudinal direction

Fig. 3 3. The tension test of the flat-knot nets torn in their transverse direction

Fig. 3-4. The tension test of the trawler's-knot nets torn in their transverse direction

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